ACME PDR Agenda

8:00	Welcome/Introduction	M. Hickman
8:05	Engineering Panel Charter	M. Hickman
8:15	ACME Schedule	M. Hickman
8:25	SpaceDoc Project Overview	B. Borowski
8:40	Engineering Design/Development	K. Adney
	Breadboard Test Summary	
	Requirements Flow	
	ACME Core Capabilities	
9:00	Diagnostics Design	S. Lawn
9:20	ACME Avionics Package/Control Systems	M. Medved
9:40	Electronics/Power	T. Gobeli
10:00	ACME Chamber Insert Assembly	A. Drake
10:20	ACME Software	M. Medved
10:40	Break	
10:50	Operations	K. Adney
11:10	Integration	C. Rogers
11:30	SRM&QA	W. Borrelli
12:00	Lunch	

ACME PDR Agenda

12:30	Requirements Compliance/Verification	K. Adney
1:00	Project Readiness	B. Borowski
1:10	ACME Science Assessment	D. Stocker
1:30	NASA Management Comments	M. Hickman
1:45	Break	
2:00	Panel Caucus	
3:00	Panel Feedback	T. O'Malley

Advanced Combustion via Microgravity Experiments (ACME)

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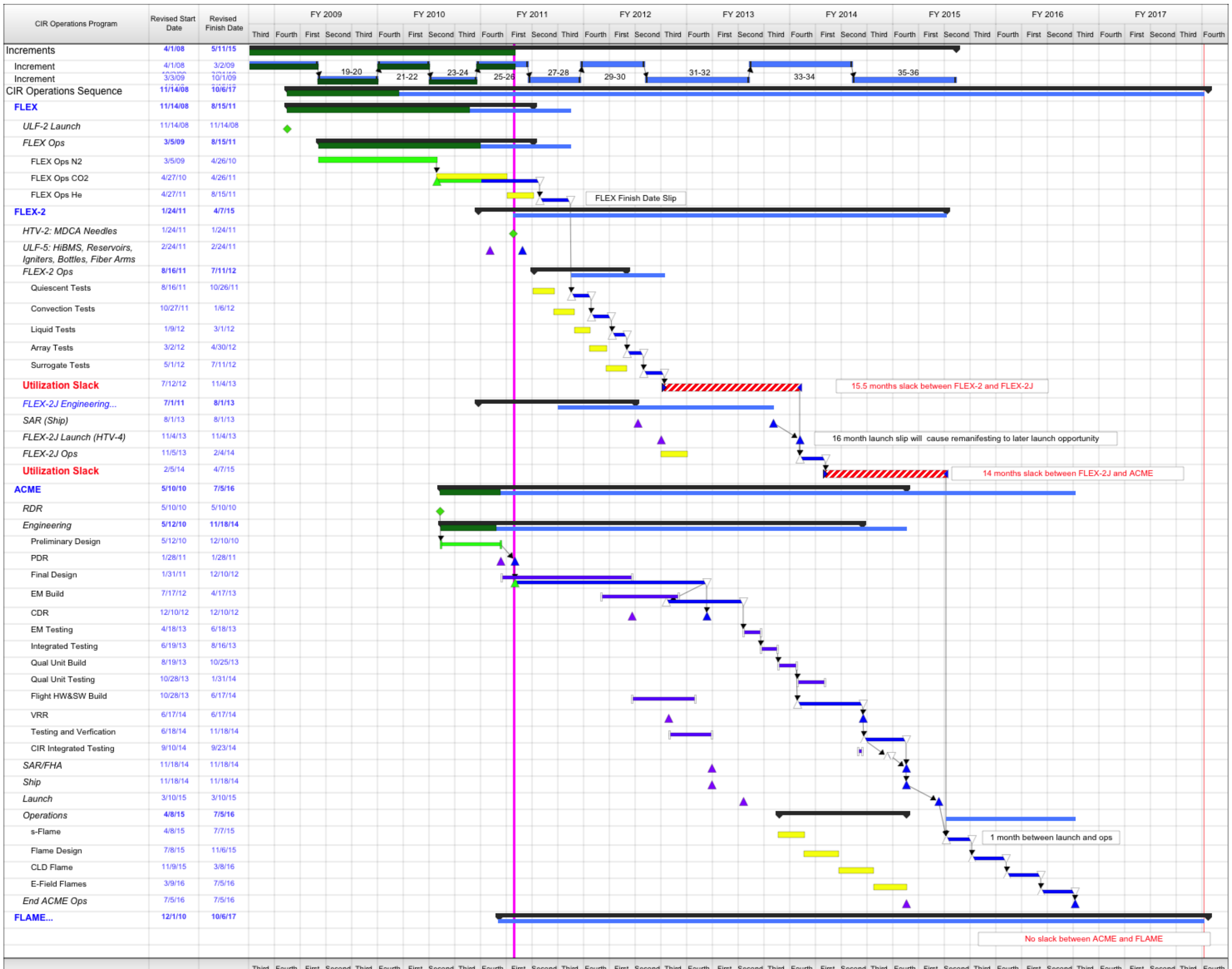
CIR Utilization Plan

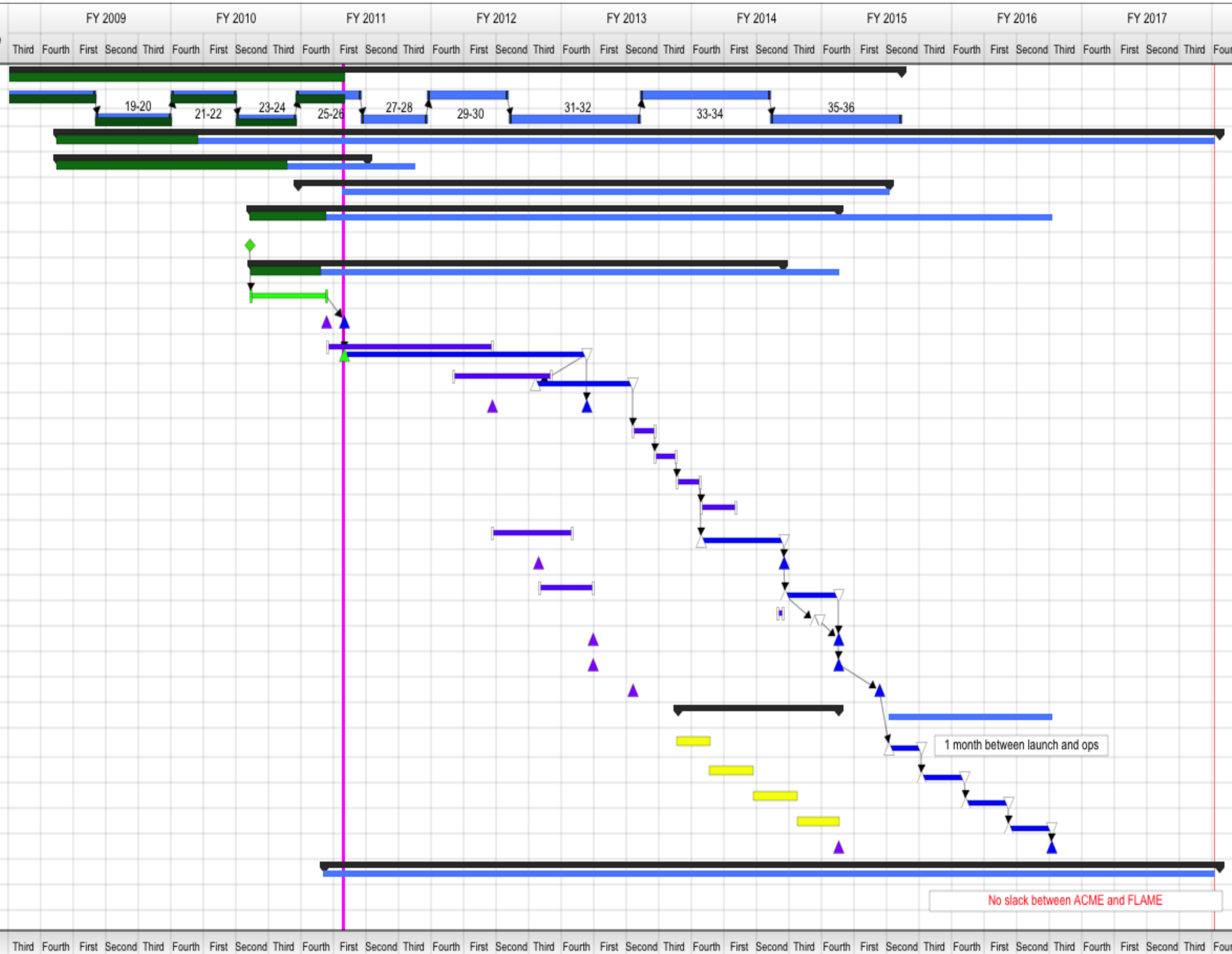
ACME



Advanced Combustion via Microgravity Experiments (ACME)

ACME Top-Level Schedule

CIR Operations Program	Revised Start Date	Revised Finish Date
Increments	4/1/08	5/11/15
Increment	4/1/08	3/2/09
Increment	3/3/09	10/1/09
CIR Operations Sequence	11/14/08	10/6/17
FLEX...	11/14/08	8/15/11
FLEX-2...	1/24/11	4/7/15
ACME	5/10/10	7/5/16
RDR	5/10/10	5/10/10
Engineering	5/12/10	11/18/14
Preliminary Design	5/12/10	12/10/10
PDR	1/28/11	1/28/11
Final Design	1/31/11	12/10/12
EM Build	7/17/12	4/17/13
CDR	12/10/12	12/10/12
EM Testing	4/18/13	6/18/13
Integrated Testing	6/19/13	8/16/13
Qual Unit Build	8/19/13	10/25/13
Qual Unit Testing	10/28/13	1/31/14
Flight HW&SW Build	10/28/13	6/17/14
VRR	6/17/14	6/17/14
Testing and Verfication	6/18/14	11/18/14
CIR Integrated Testing	9/10/14	9/23/14
SAR/FHA	11/18/14	11/18/14
Ship	11/18/14	11/18/14
Launch	3/10/15	3/10/15
Operations	4/8/15	7/5/16
s-Flame	4/8/15	7/7/15
Flame Design	7/8/15	11/6/15
CLD Flame	11/9/15	3/8/16
E-Field Flames	3/9/16	7/5/16
End ACME Ops	7/5/16	7/5/16
FLAME...	12/1/10	10/6/17



ACME Preliminary Design Review

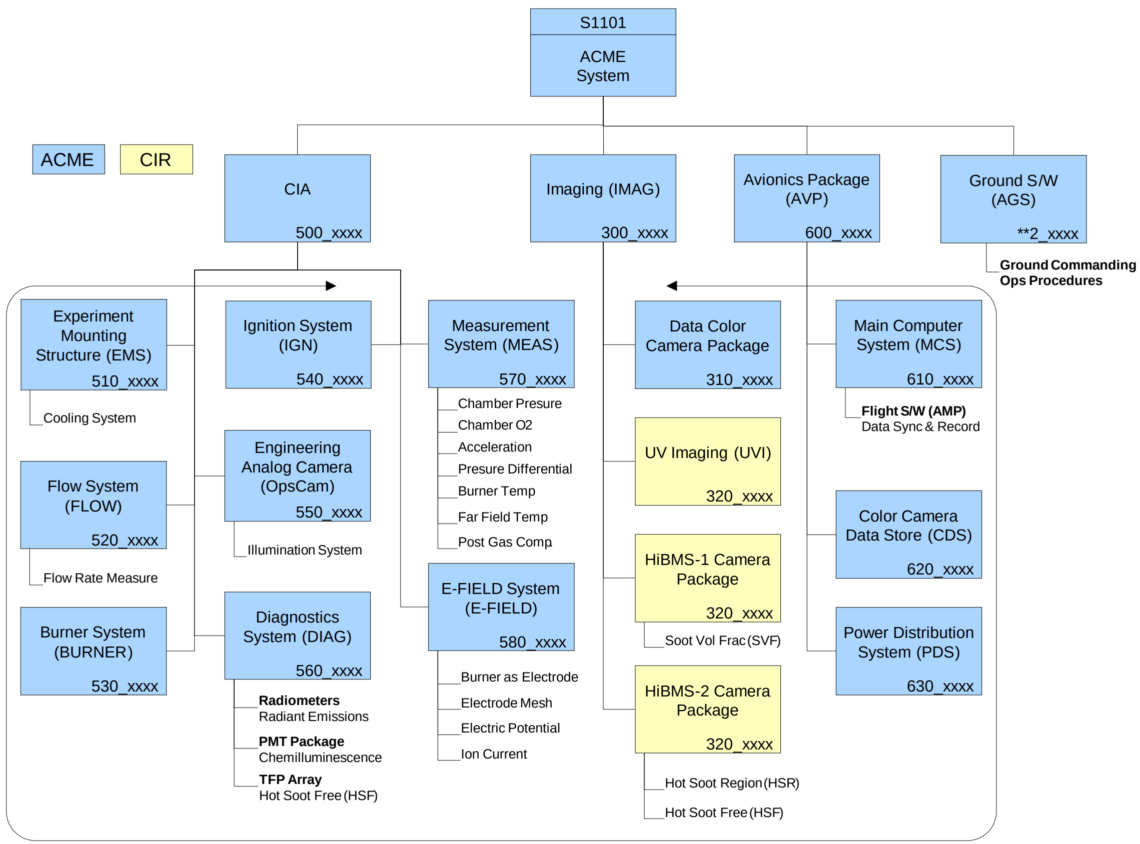
Engineering Design Presentation

SpaceDoc ACME Project Overview

Brian Borowski
ACME Engineering Lead

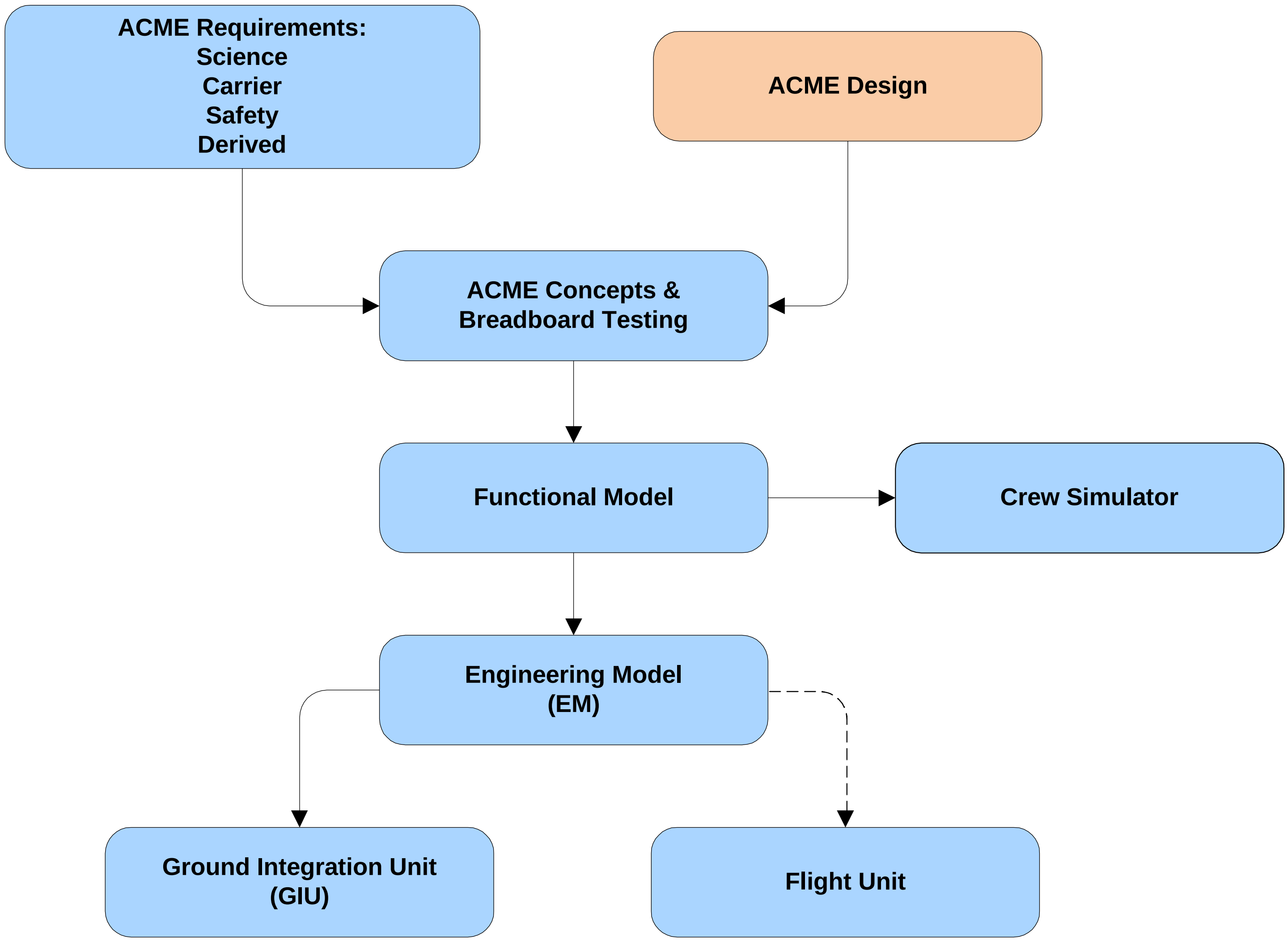
Advanced Combustion via Microgravity Experiments (ACME)

- The ACME **Product Breakdown Structure (PBS)** has 3 main development systems identified: Chamber Insert Assembly (CIA), Imaging System (IMAG), Avionics Package (AVP).
- These, along with CIR provided systems, address all the functional needs of ACME as defined by the Science Requirements and are further decomposed into functional sub-systems



ACME Subsystems

ACME Development Plan



SpaceDoc ACME Contract Status

•ACME SpaceDoc involvement began in 2007

•ACME Science Concept Review was held in February 2008

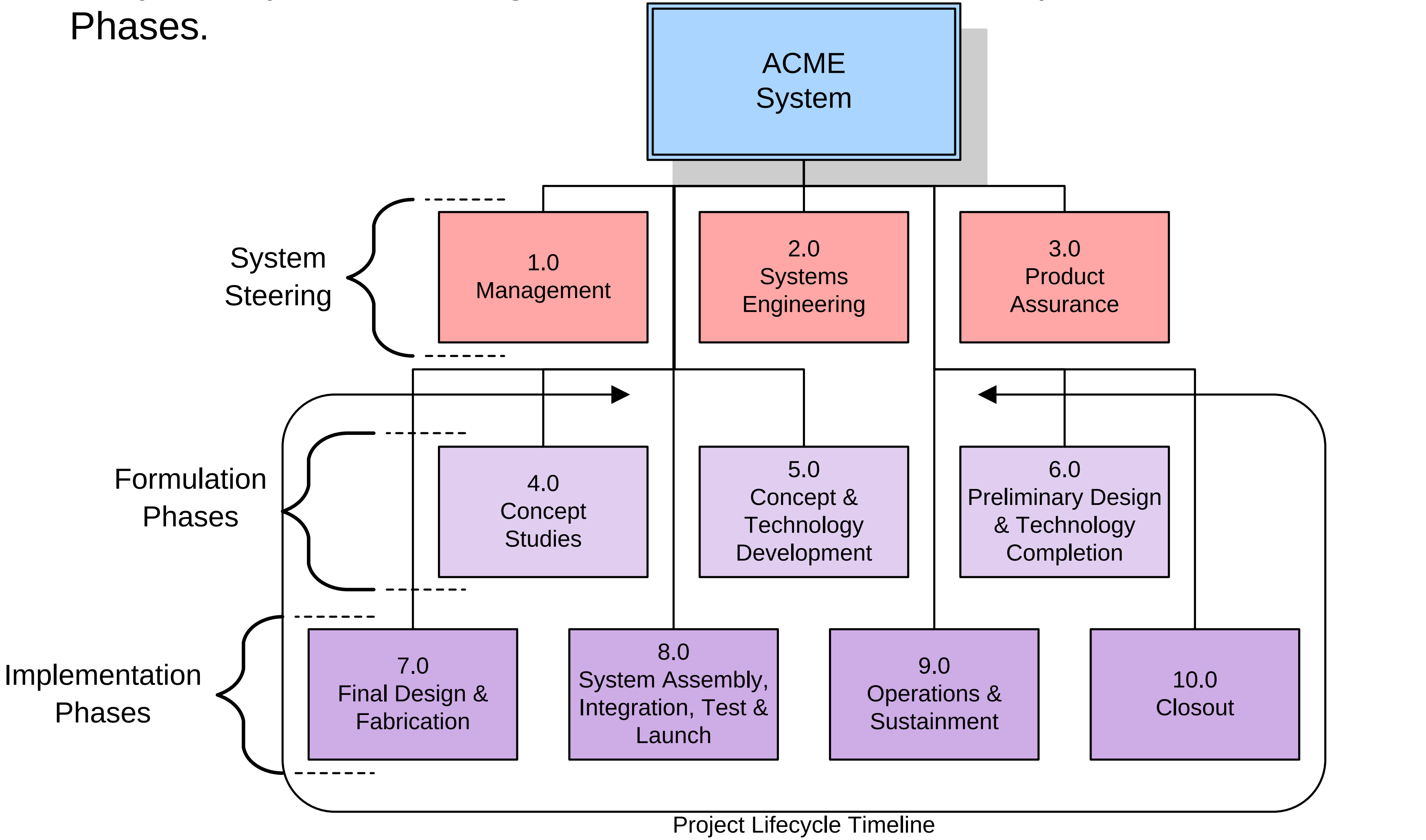
•ACME Requirements Definition Review was held in May 2010

•The ACME SpaceDoc work is assigned as incremental Delivery Orders (Dos) to ZIN Technologies under the SpaceDoc contract

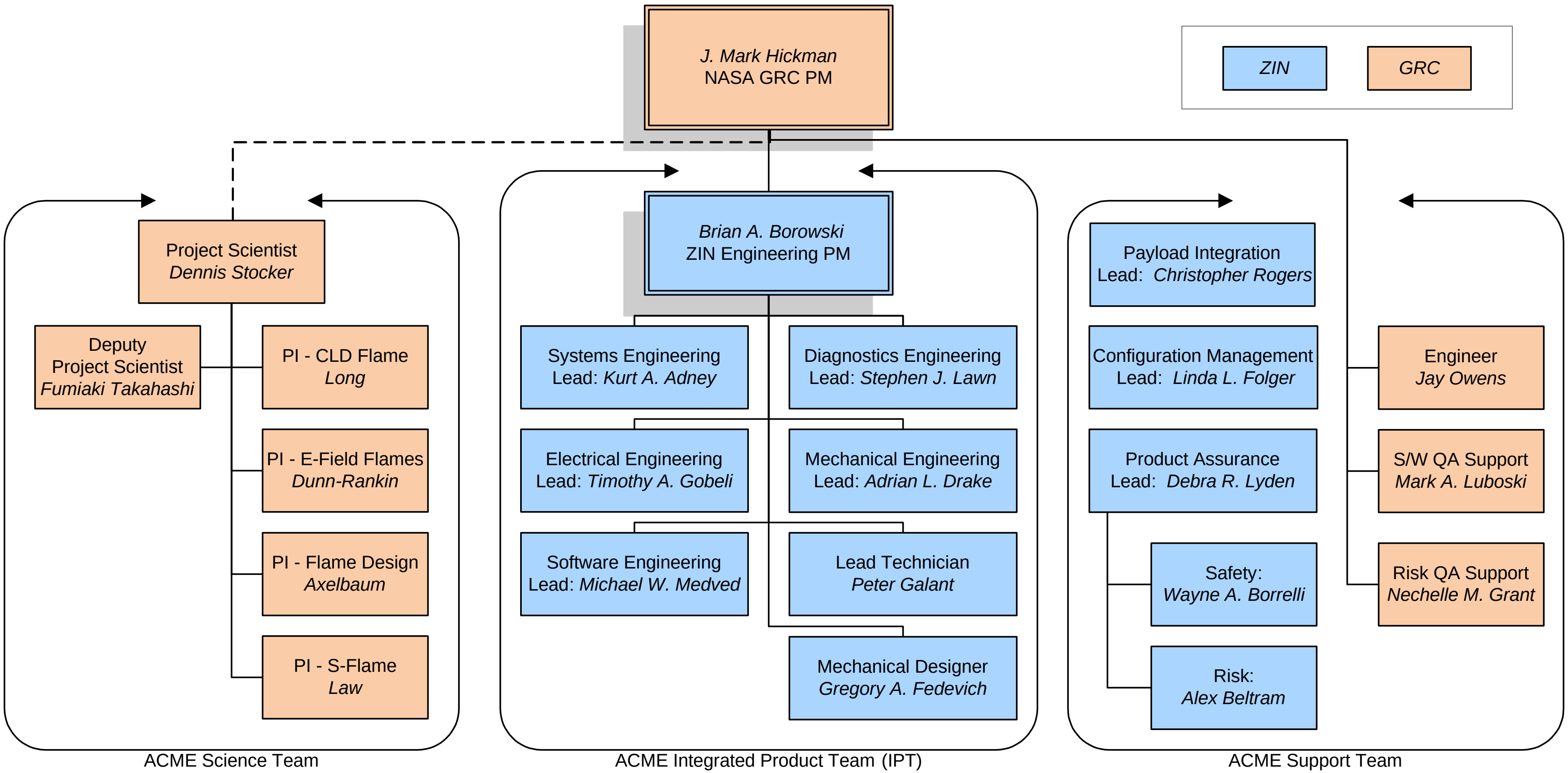
•Current Delivery Order contract began in October 2010 and continues through March 2012

Advanced Combustion via Microgravity Experiments (ACME)

- The ACME Cost Account Level (CAL) Work Breakdown Structure (WBS) has 3 main development areas identified throughout the project lifecycle: System Steering, Formulation Phases, and Implementation Phases.



ACME Project Organization



Engineering Design/Development Breadboard Test Summary

Kurt Adney
ACME Systems Engineering Lead

Breadboard Testing Summary

Test	Goal	Result Summary
Mass Flow Controller Test	Determine functionality/control of MFCs	Controlled Mass Flow Controller power (through relay circuitry) as well as flow control input and monitored flow out via Cube with a Laptop running LabView
Igniter Test	Determine functionality/control of igniter	Enabled igniter (through relay circuit) and controlled output voltage via Cube with a Laptop running LabView .
High Voltage Module Test	Determine functionality/control of HV Module	Enabled High Voltage module and controlled output via Cube with a Laptop running LabView .
Ion Current Test	Establish ion current reading from HV Module	Read equivalent ion current of High Voltage Supply via Cube with a Laptop running LabView .

Breadboard Testing Summary

Test	Goal	Result Summary
Thermocouple Test	Determine functionality/control of Thermocouples	Read thermocouple temperature via Cube with a Laptop running LabView .
Motor Controller Board/Stepper Motor Test	Determine functionality/control of motor and control board	Operated stepper motor for igniter via Motor Controller Board via Ethernet connection with a Laptop running LabView .
SBC Test	Determine functionality/control using the single board computer	All the preceeding functionality/control operations were redone with the exception of the Prodigy Motion Controller via the Single Board Computer controlling the Cube via Ethernet.
Flow/Ignition System Test	Determine functionality/control of integrated systems	Successfully repeatedly ignited prototype co-flow burner at various flow rate combinations.

Breadboard Testing Summary

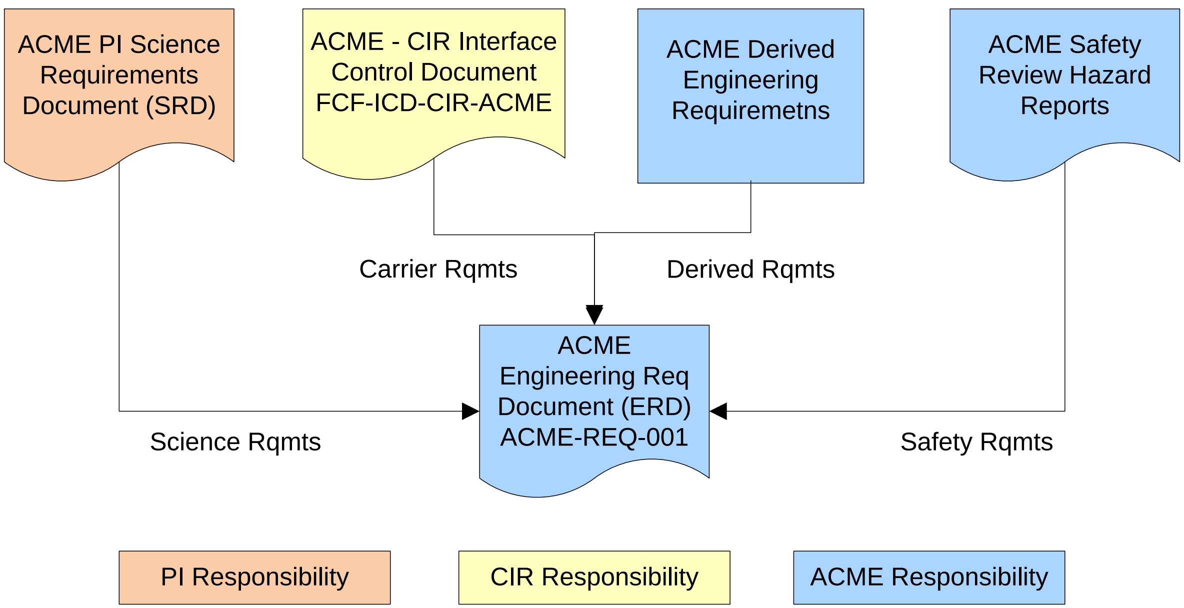
Test	Goal	Result Summary
Zoom Lens Test	Determine functionality/control of the color camera zoom lens	Basic functional testing including extensive work with electrical control of Zoom & Iris stepper motors with the ACME platform
Radiometer Test	Determine functionality/control of the radiometers	Radiometer testing using a propane flame as a source demonstrated ACME Radiometer concept
Analog Camera Test	Determine functionality/control of the analog camera	Analog Camera testing w/ off-the-shelf components: Camera, Lens & Mirror (@ 45°) demonstrated ACME Analog Camera concept
PMT Test	Determine functionality/control of the photomultiplier tubes	PMT testing using an incandescent bulb as a source demonstrated qualitative initial PMT response

Engineering Design/Development
Requirements Management

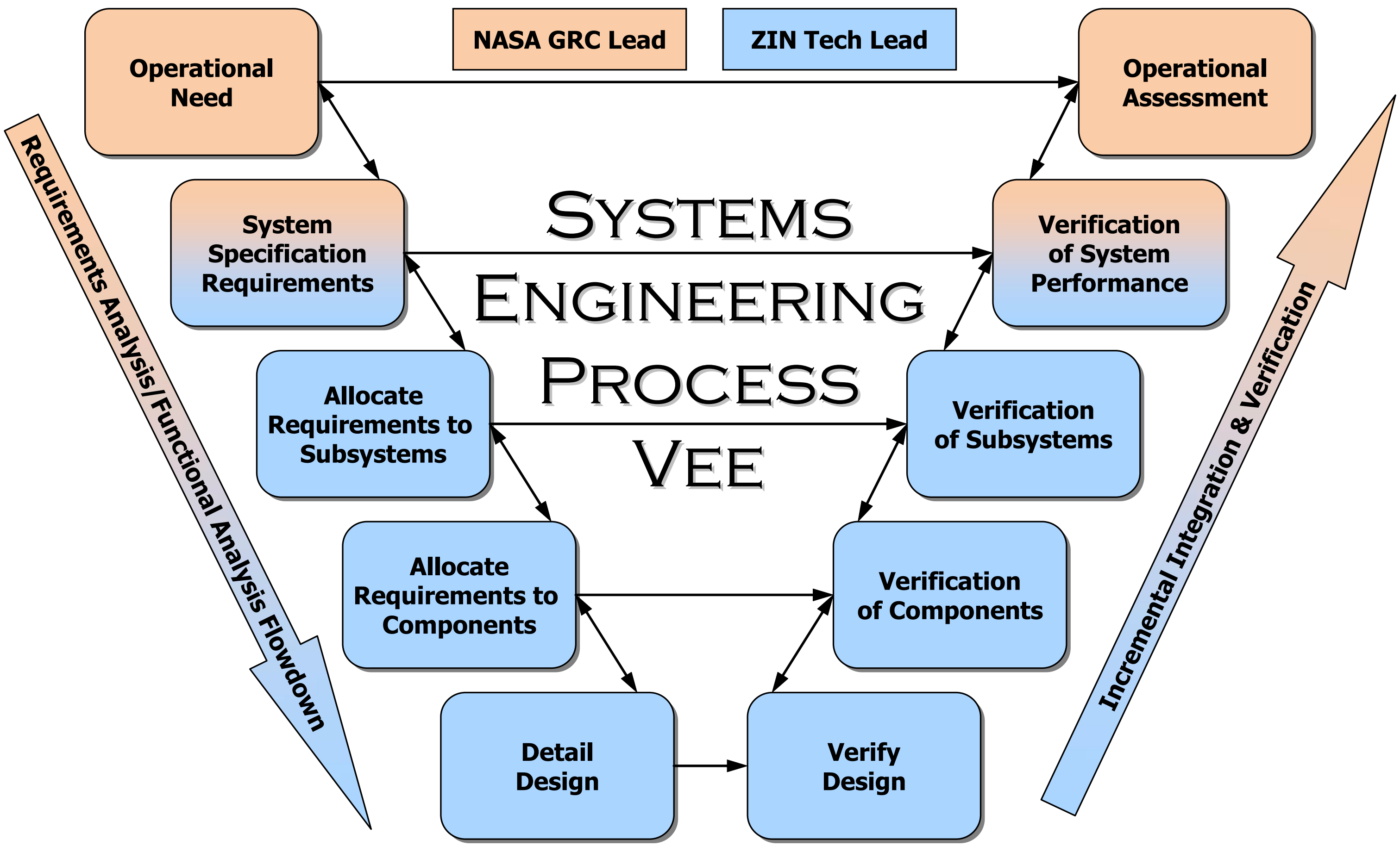
Kurt Adney
ACME Systems Engineering Lead

ACME Requirements Flow

- The ACME Science Requirements are part of a larger set of ACME project requirements consisting of science, interface and safety requirements both derived by ACME and imposed upon ACME
- All ACME project requirements are captured in the ACME Engineering Requirements Document (ERD)



ACME Requirements in the SE Process Structure



Sample ERD Requirement Text

System	SSC_ID	SRD Trace	ERD REQ Title/Description
		1.1	**General Experiment Configuration** ACME shall provide non-measurement requirements.
BURNER	530_0010	1.1.1	**Burners – Installation** The CIA BURNER HWCI shall install a single burner one at a time within the CIR chamber.
BURNER	530_0020	1.1.2	**Burners – Exchangeable** The CIA BURNER HWCI shall provide that all burners are exchangeable during spaceflight.
BURNER	530_0030	1.1.2	**Burners – ORU** The CIA BURNER HWCI shall provide all burners as ORUs.
BURNER	530_0040	1.1.3	**Burners - Duplicate to PS** The CIA BURNER HWCI shall provide at least one duplicate of each burner to the Project Scientist except where burners with different tube lengths are otherwise identical, then only one such burner is required for transfer to the Project Scientist.
FLOW	520_0010	1.1.4.1	**Flow H/W Compatibility – Hydrogen to Chamber Entrance** The CIA FLOW HWCI shall provide the gas delivery system compatible with the gaseous fuel hydrogen.
BURNER	530_0050	1.1.4.1	**Burner H/W Compatibility – Hydrogen to Chamber Entrance** The CIA BURNER HWCI shall provide all burners compatible with the gaseous fuel hydrogen.

- Requirement Decomposition Metrics
  - Pre-RDR – 329 requirements
  - Post RDR – 523 requirements

ACME Core Experiment Elements

- The core components of gaseous combustion support flow and regulation of gases to the chamber and ignition of those gases.
- Imaging, Diagnostic and Measuring devices are present for all experiments.

- Other PI-specific components include:
  - Exchangeable burners of different types – spherical, gas-jet, coflow
  - Igniter tips
  - E-field circuitry and mesh electrode
  - Thin Filament Pyrometry (TFP)
  - Color Camera changeable filter

- PIs build on these core capabilities to make their experiments unique and the engineering team adds PI-specific components to these elements to accomplish the scientific mission goals.

Diagnostics Concepts

Steve Lawn
ACME Diagnostics Engineering Lead

Advanced Combustion via Microgravity Experiments (ACME)

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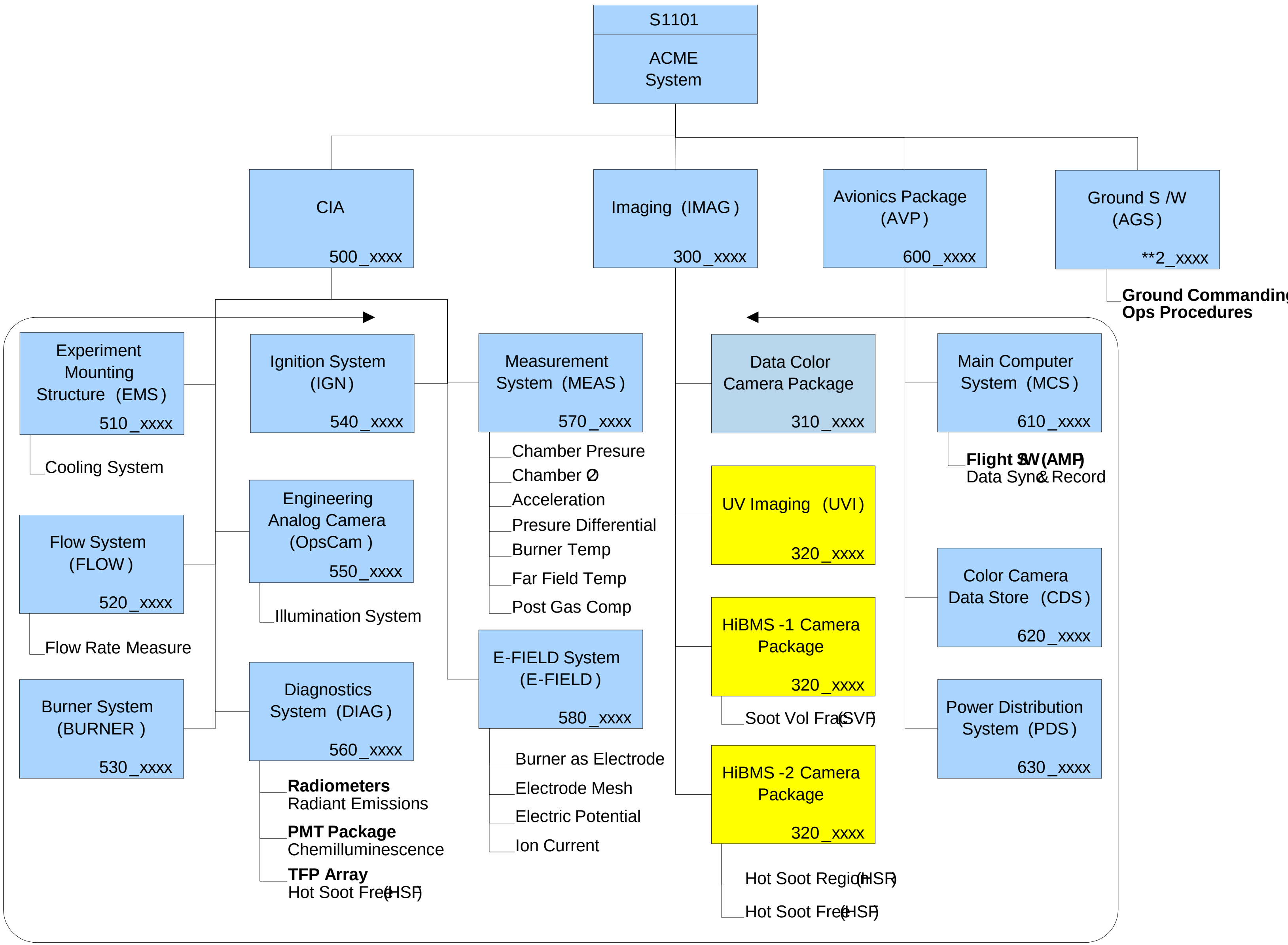


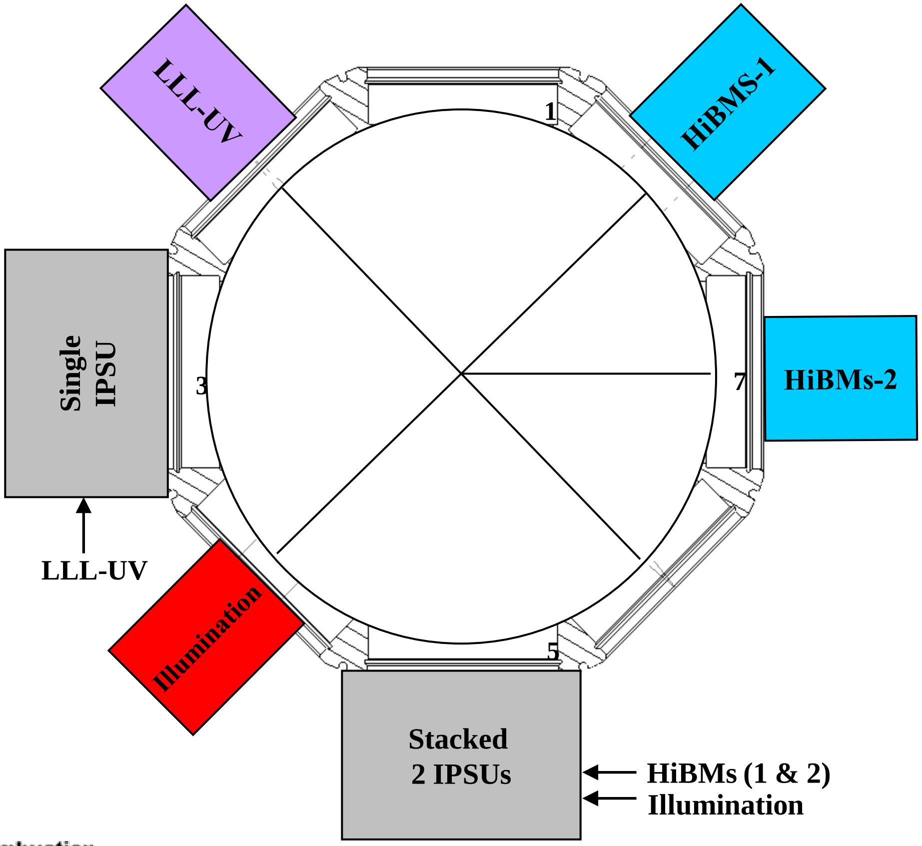
ACME Subsystems

Advanced Combustion via Microgravity Experiments (ACME)

ACME Diagnostics

CIR Provided

(shown in FLEX-2 Layout)



HiBMs Package/Illumination Package

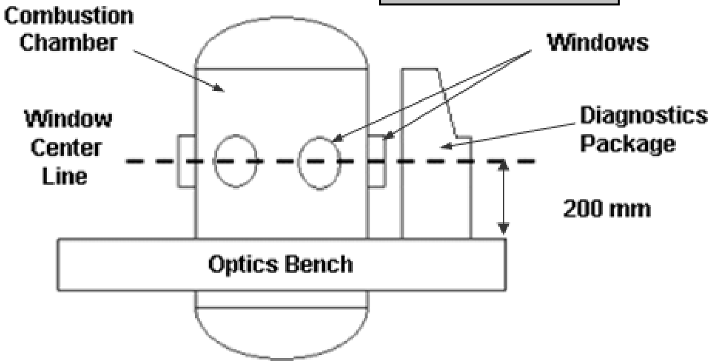
- Soot Volume Fraction
- CIR Illumination used as backlight
- FOV: 90 mm – CIR To Provide

HiBMs-2 Package

- Soot Temperature Imaging & Thin Filament Pyrometry
- Used with LCTF (650 – 1050 nm)
- FOV: 50 mm – On orbit

LLL-UV Package

- OH* Flame Imaging
- FOV: 90 mm – CIR To Provide



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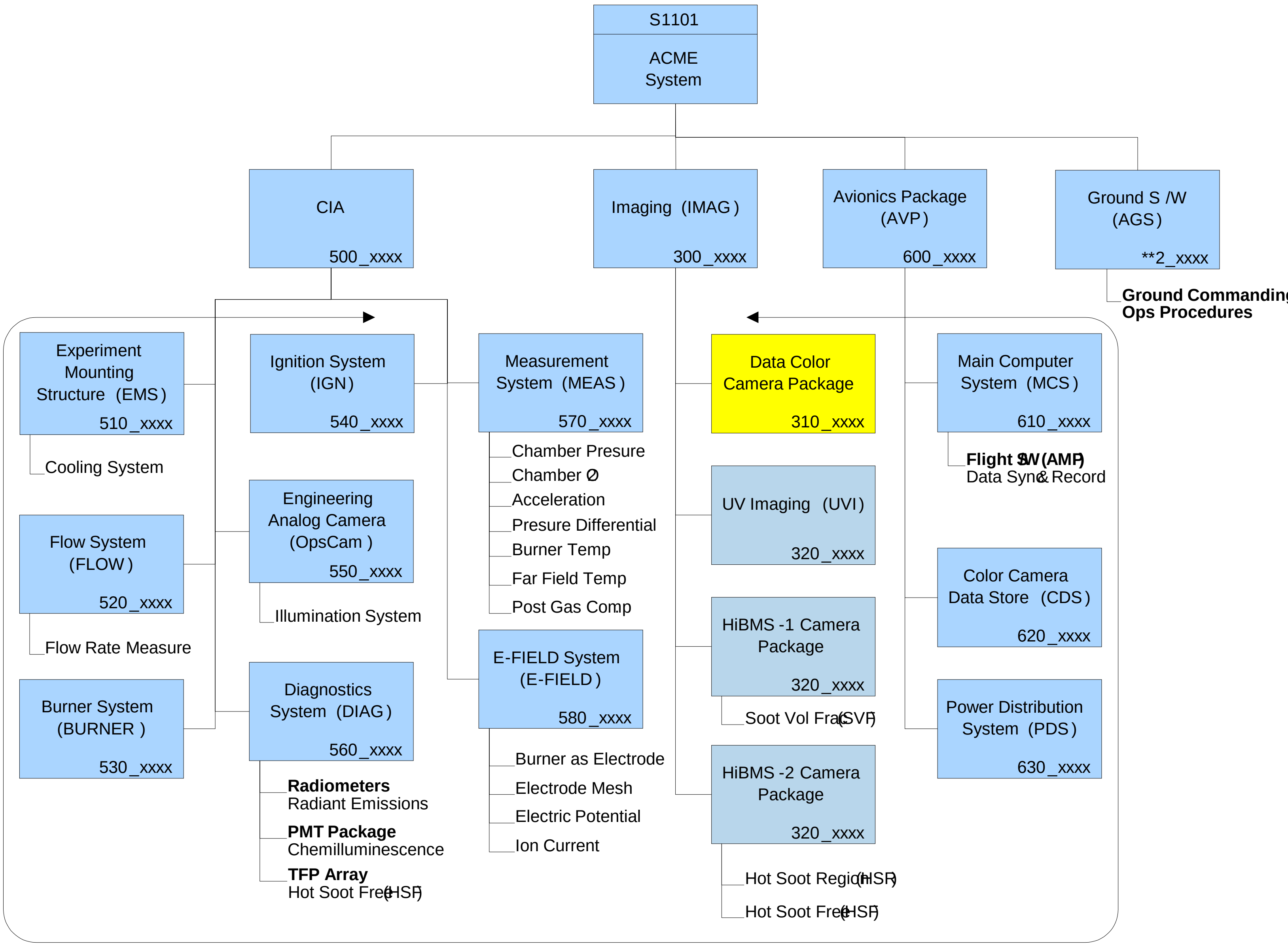
Advanced Combustion via Microgravity Experiments (ACME)

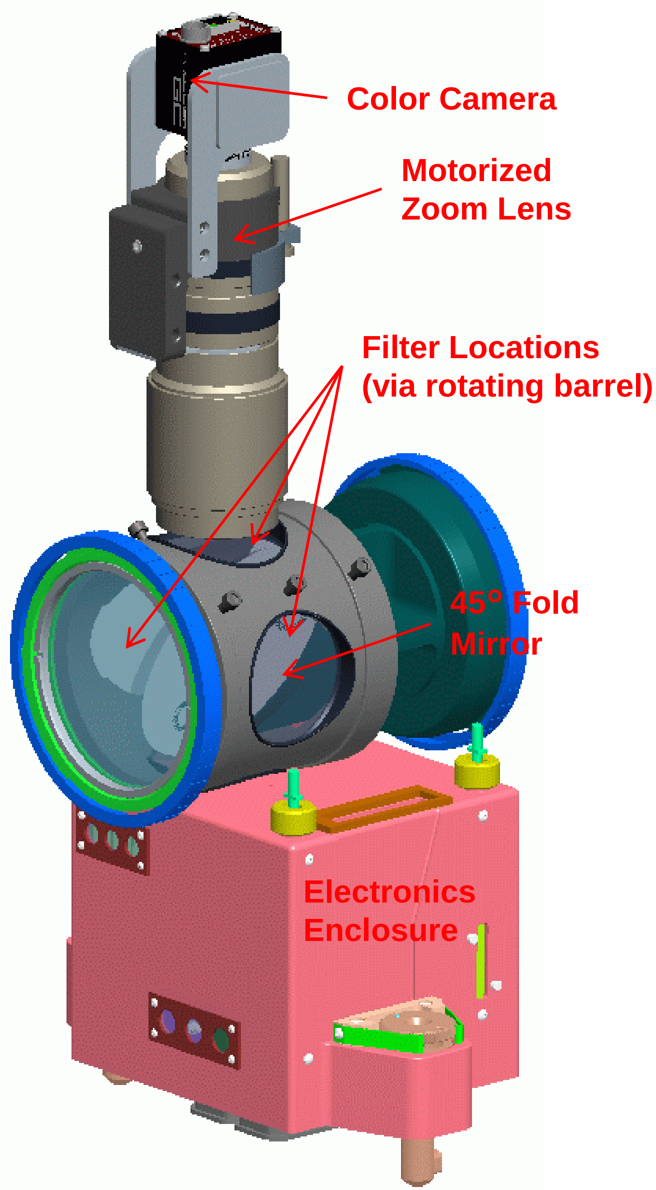


ACME Subsystems

ACME Diagnostics

ACME Color Camera Package

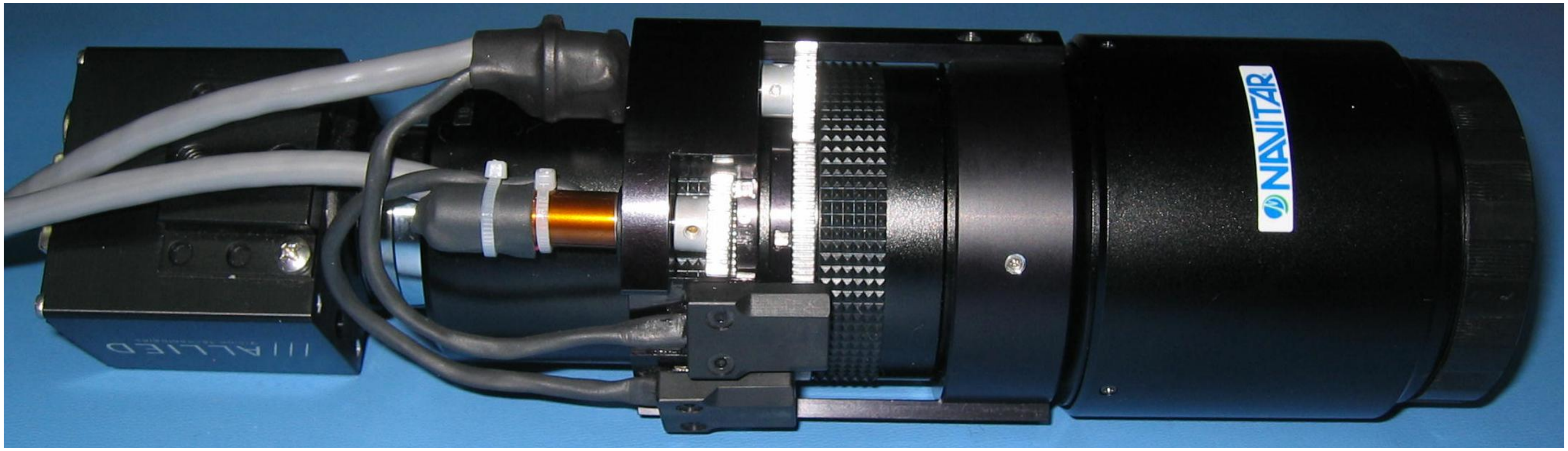
- ACME Provided Diagnostic Package for Color Flame Imaging
- Located outside chamber at CIR UML-6, providing forced air cooling & power
- Package will be comprised of following main components:
  - Color Camera – Allied Vision: GC-1380CH
  - Zoom Lens – Navitar: Zoom 7000 (w/ motorized Zoom & Iris)
  - Folding Mirror
  - Blue-Green Filter – Schott BG-7
- Mechanical design concept leveraged from general CIR Diagnostic Package format



ACME Diagnostics

ACME Color Camera Package (cont.)

- Prototype of the Motorized Navitar Zoom 7000 was delivered in November 2010
- Development testing has included basic functional testing as well as extensive work with electrical control of the Zoom & Iris stepper motors using the ACME platform



Advanced Combustion via Microgravity Experiments (ACME)

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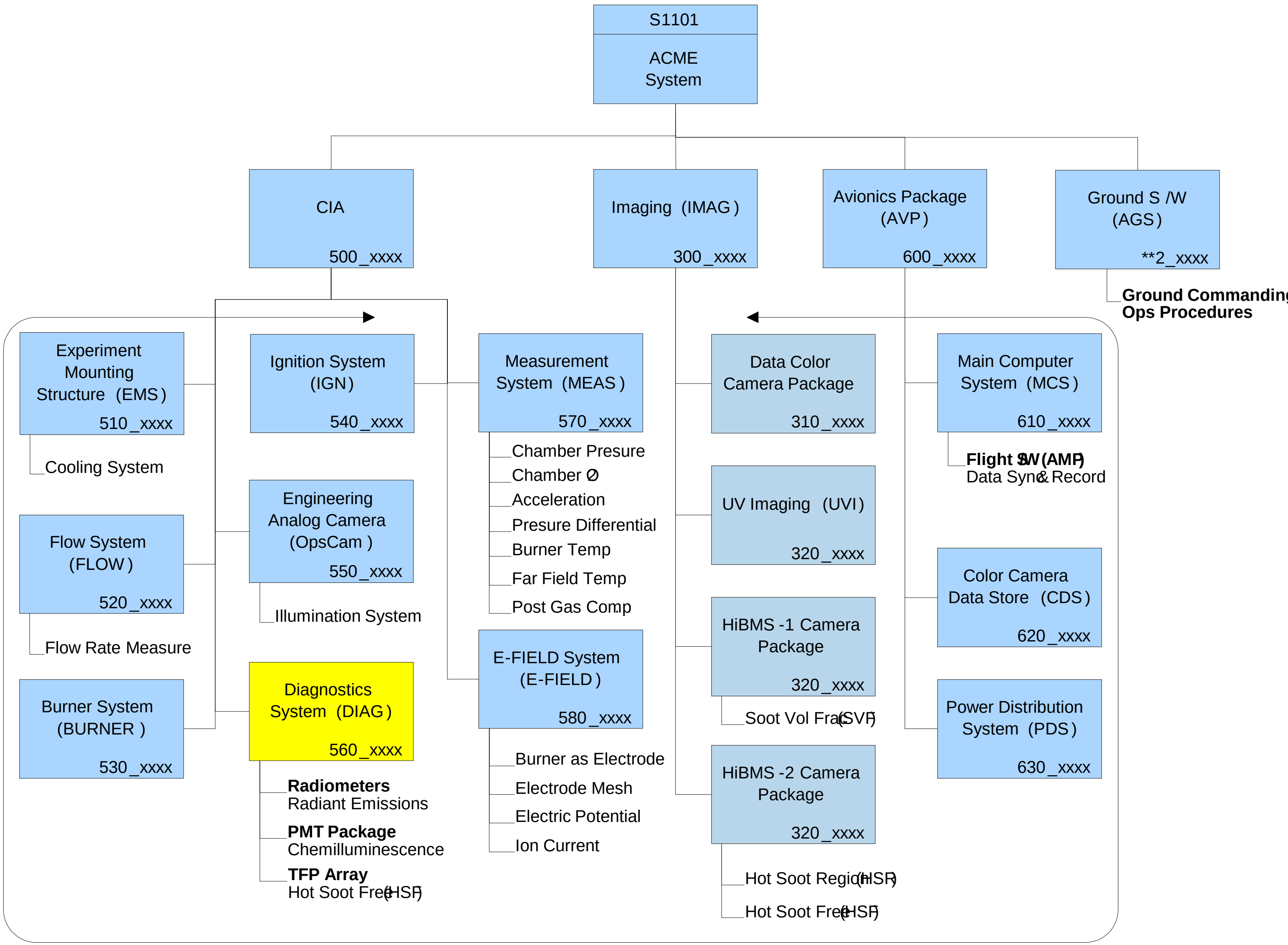
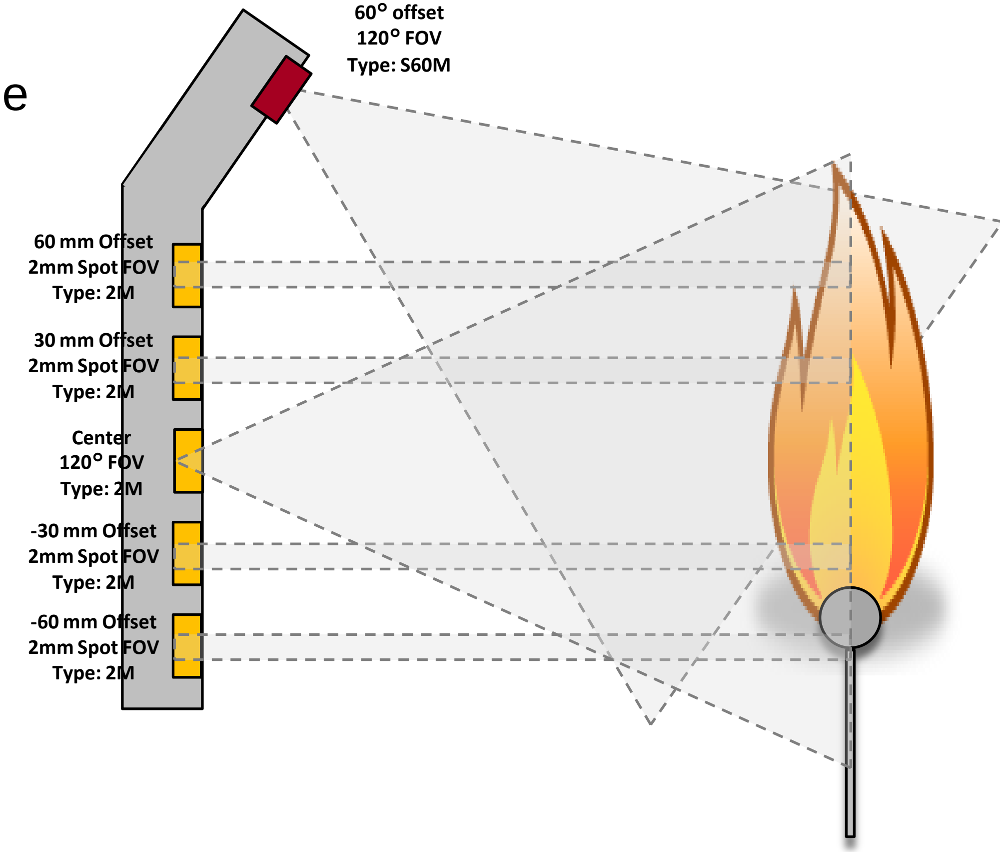


ACME Subsystems

ACME Diagnostics

ACME Radiometer Package

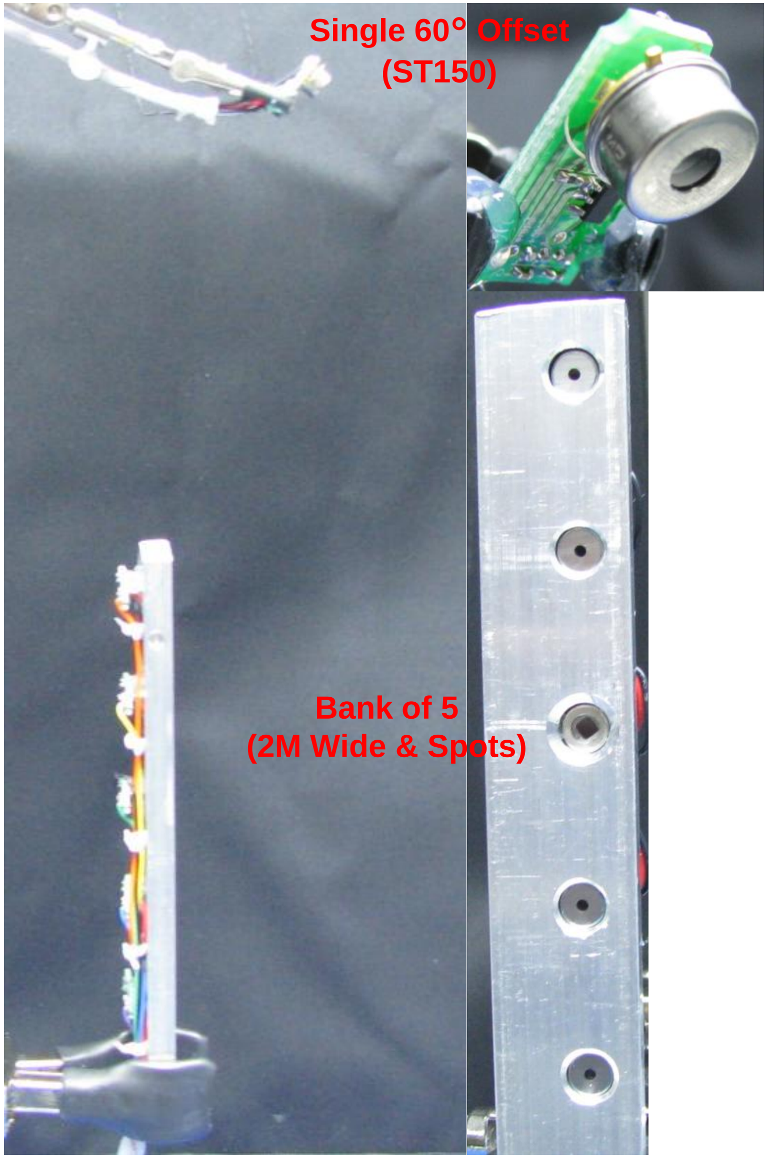
- ACME Provided Diagnostic Package for Thermal Radiation & Far Field Radiation Measurements
- Located on the Chamber Insert
- Based on following detectors:
- Dexter: 2M Thermopile:
  - Array of 5, equally spaced parallel to the flame region
  - Higher S/N Ratio
- Dexter: ST150/S60M Thermopile:
  - Single offset at 60° for far field
  - Faster response time



ACME Diagnostics

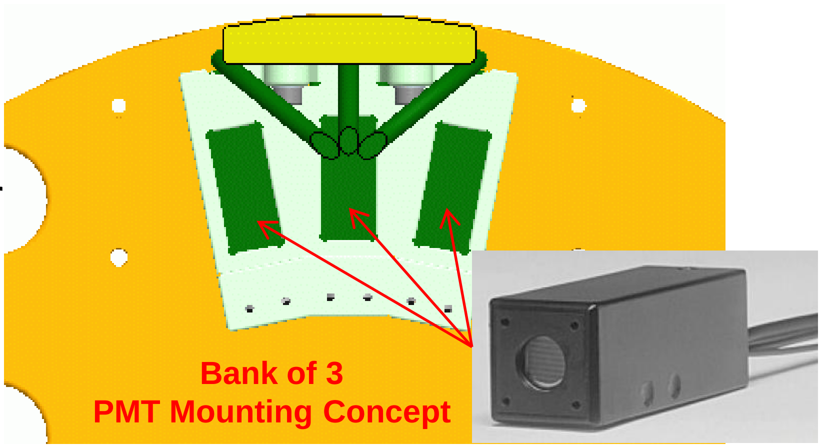
ACME Radiometer Package (cont.)

- Development testing using propane flame as an initial source demonstrated ACME Radiometer concept
- 2M Wide (w/ gain = 500) detector & 2M Spot (w/ gain = 1500) detectors positioned 140 mm from flame, produced signals ~ 4.2 V (max = 5 V)
- ST150 & S60M detectors (both w/ gain = 1000) positioned 206 mm from flame
- ST150 initially shows better signal response (~4.5 V) vs. S60M (~3.6 V) under the same flame conditions

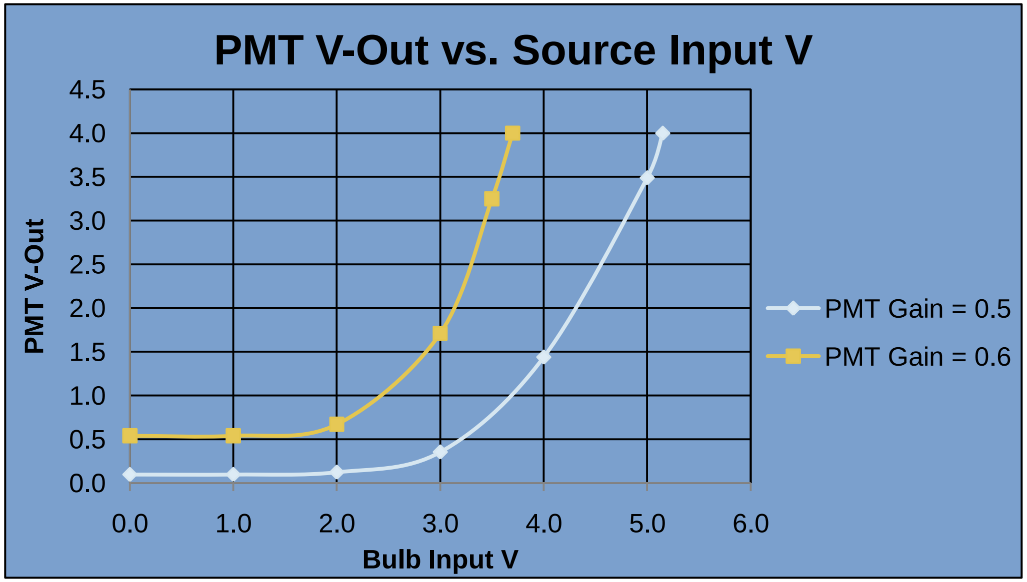


ACME Diagnostics

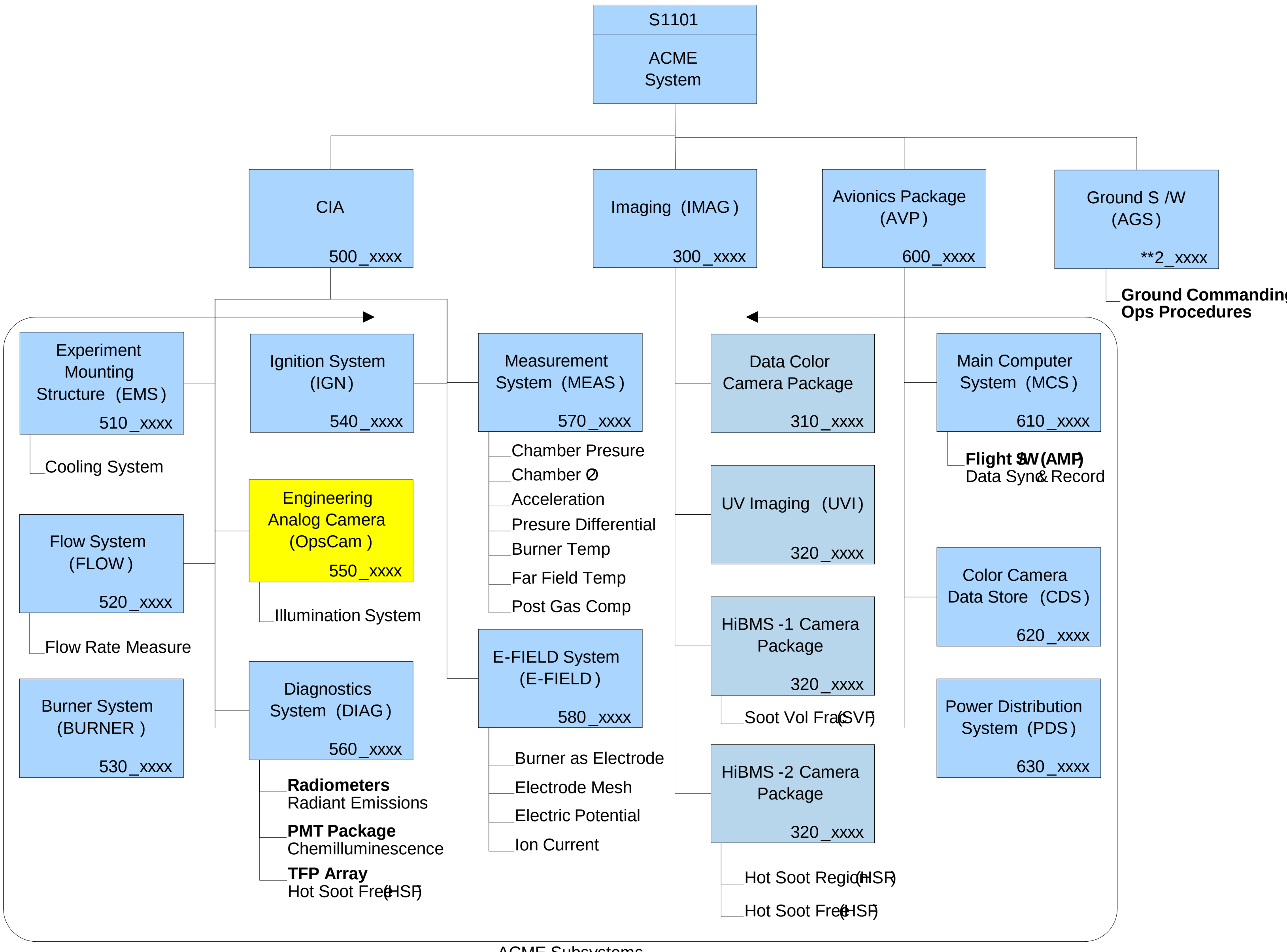
ACME PMT Package



- ACME Provided Diagnostic Package for Flame Extinction Detection & Chemiluminescent
- Located on the Chamber Insert
- Hamamatsu: H10722-110 PMT Module
- PMT Package Configuration:
  3 Modules:
  - Broadband (185 – 650 nm)
  - 310 nm (OH*) – via NB filter
  - 431 nm (CH*) – via NB filter
- Development testing using a dim incandescent bulb as a test source demonstrated qualitative initial PMT response



Advanced Combustion via Microgravity Experiments (ACME)

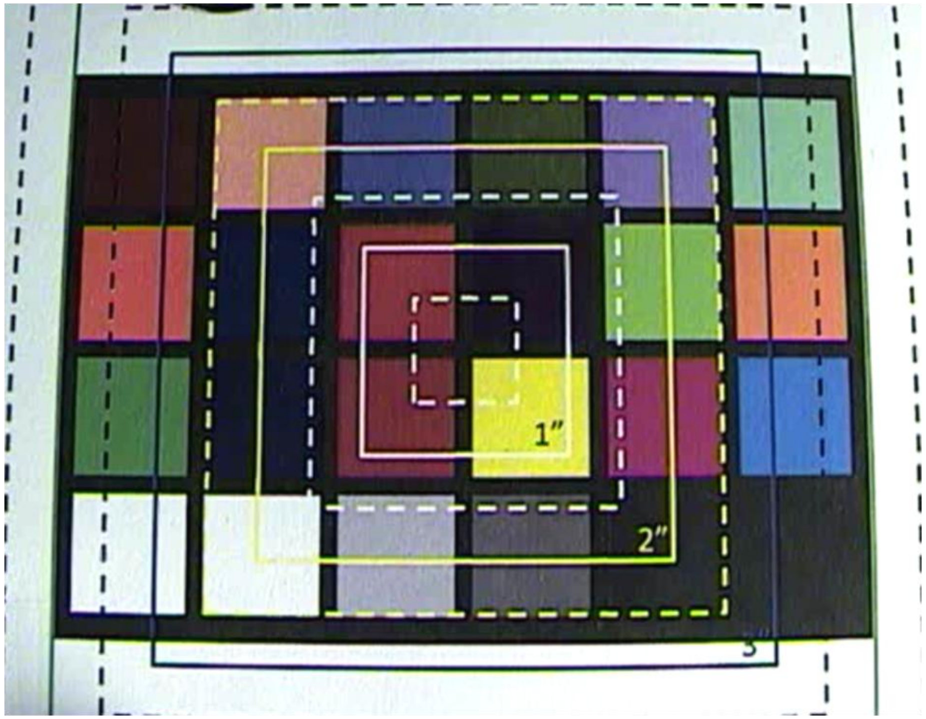


ACME Diagnostics

ACME Analog Camera Package

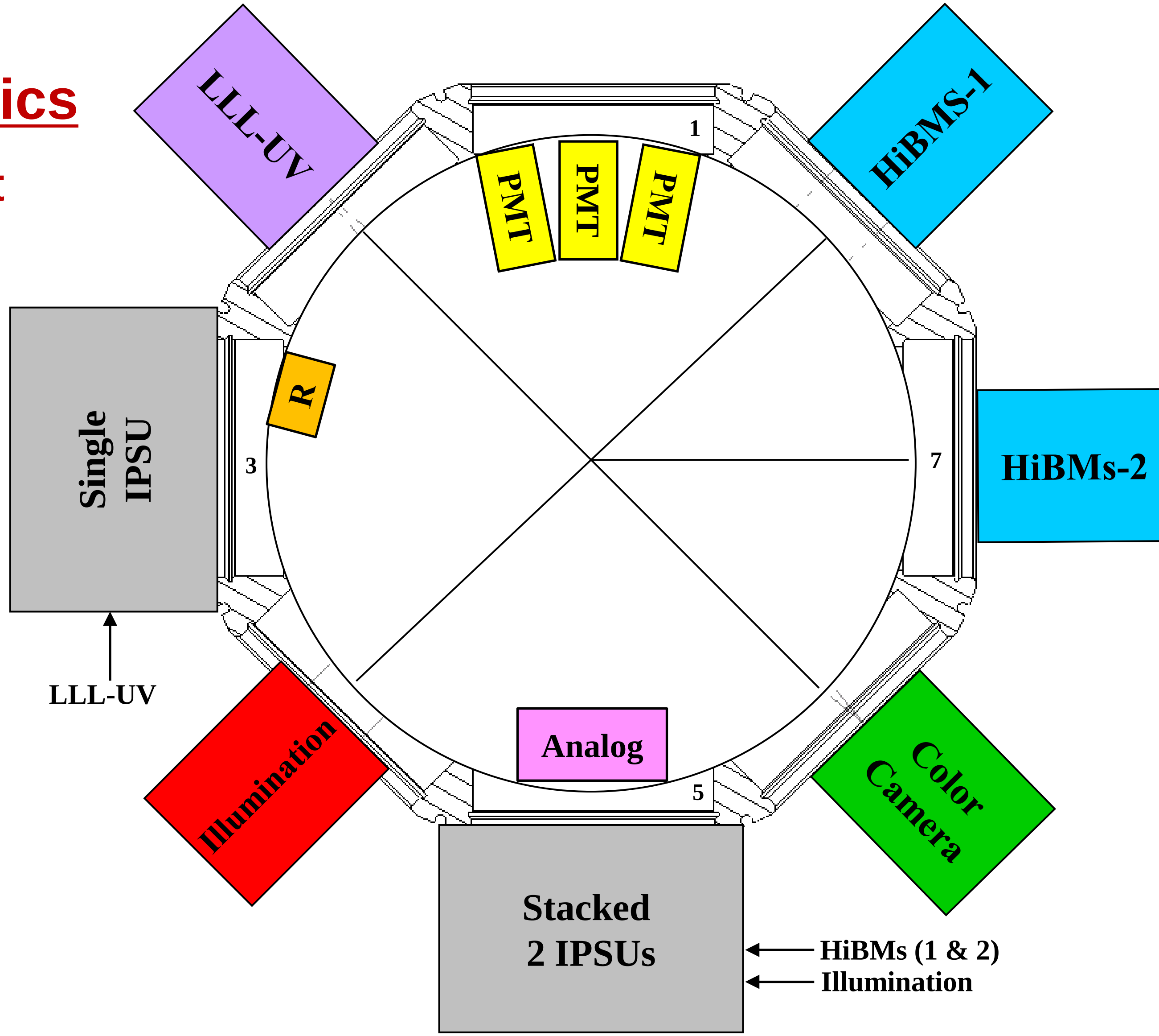
- ACME Provided Diagnostic Package for the Ops Imaging View
- Located on the Chamber Insert
- Hitachi: KP-D20B Analog Color Camera

- Development testing using off-the-shelf components: Camera, Lens, Mirror (@ 45°) & Target (see picture) demonstrated ACME Analog Camera concept
- Field of View ~ 115 mm x 86 mm



ACME Diagnostics

Layout Concept

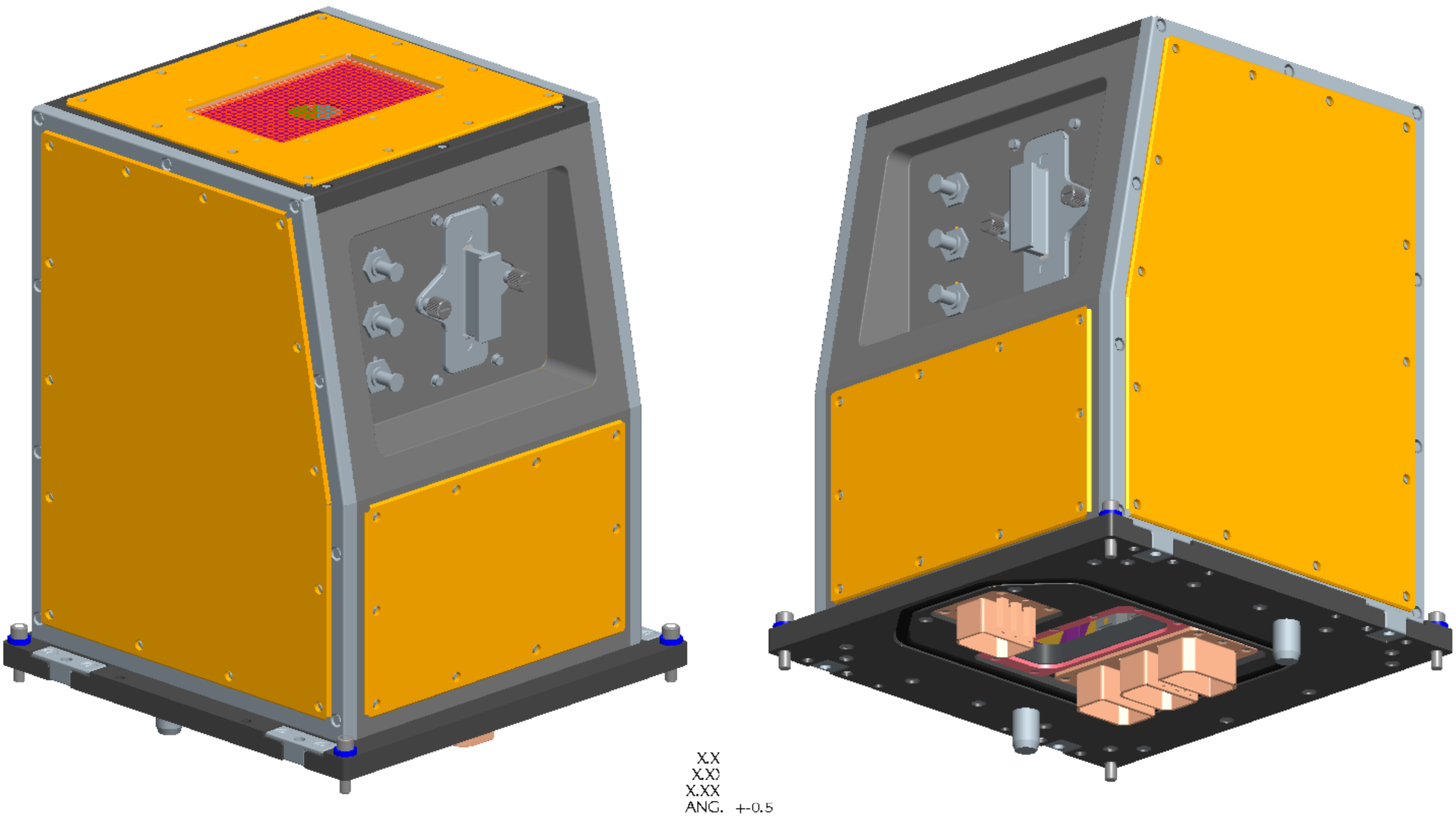


Avionics Package and Control Systems Concepts

Mike Medved

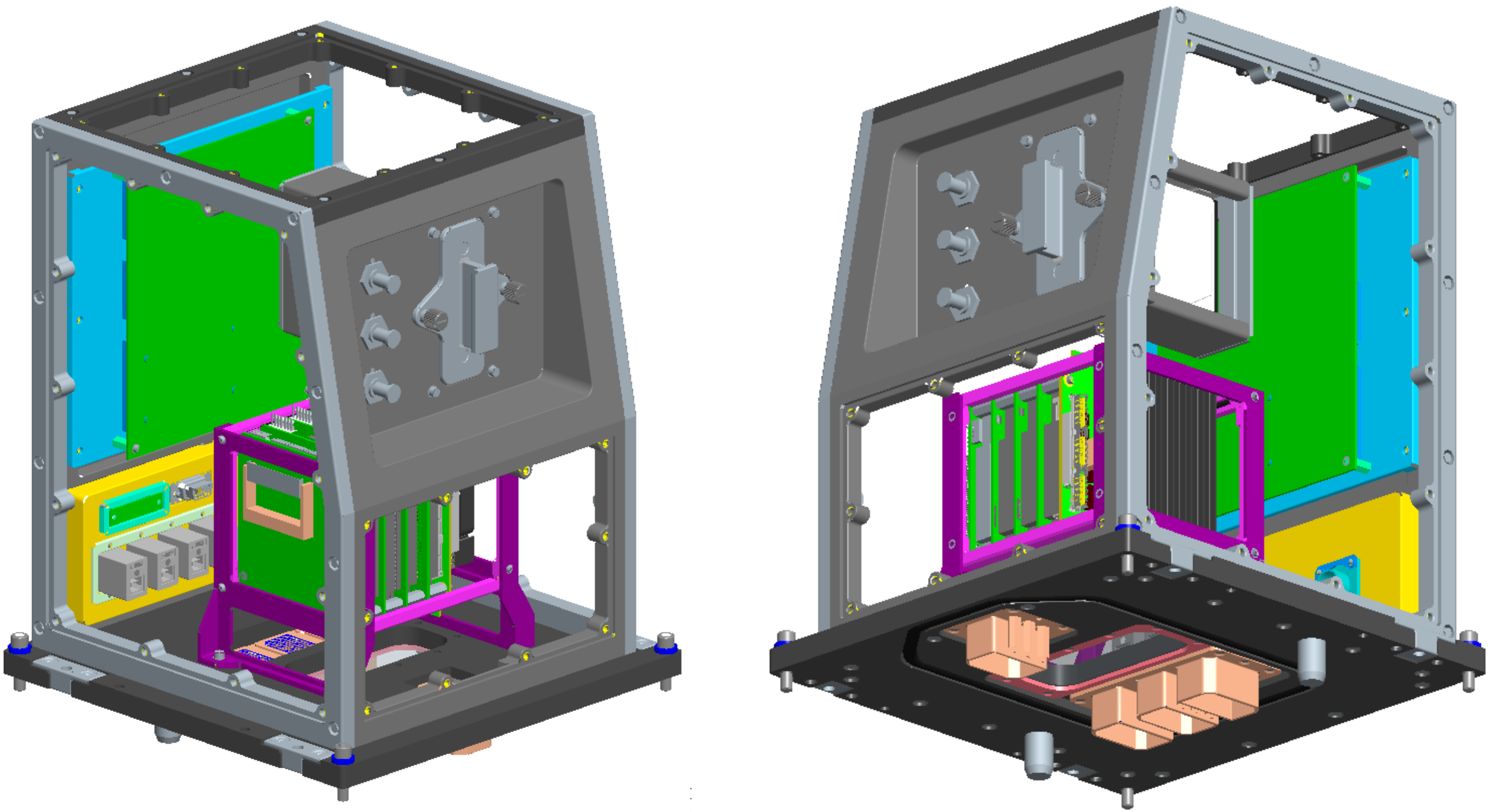
ACME Software Engineering Lead

Advanced Combustion via Microgravity Experiments (ACME)



AVP Conceptual Model

Advanced Combustion via Microgravity Experiments (ACME)



AVP Conceptual Model

Advanced Combustion via Microgravity Experiments (ACME)

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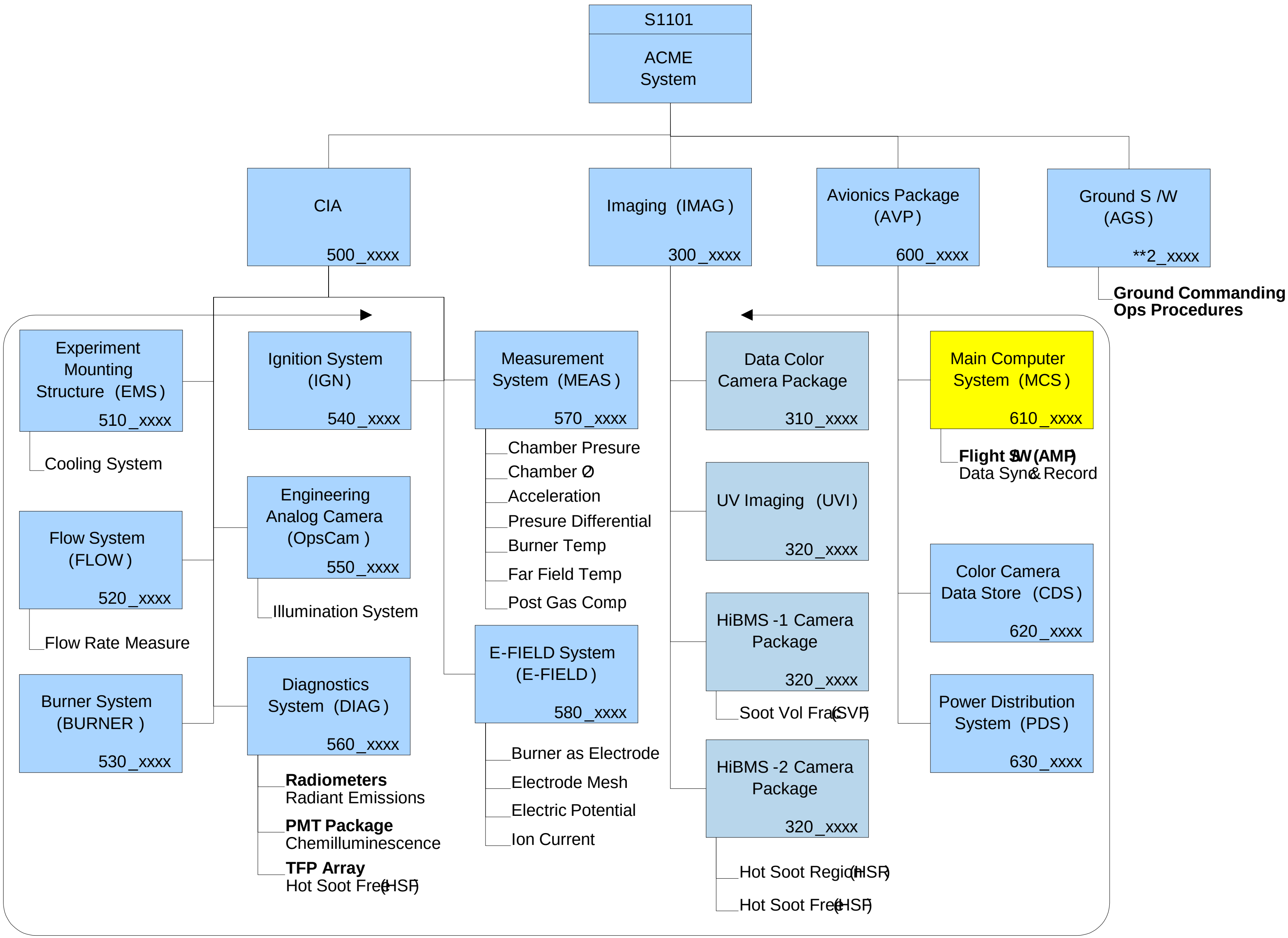
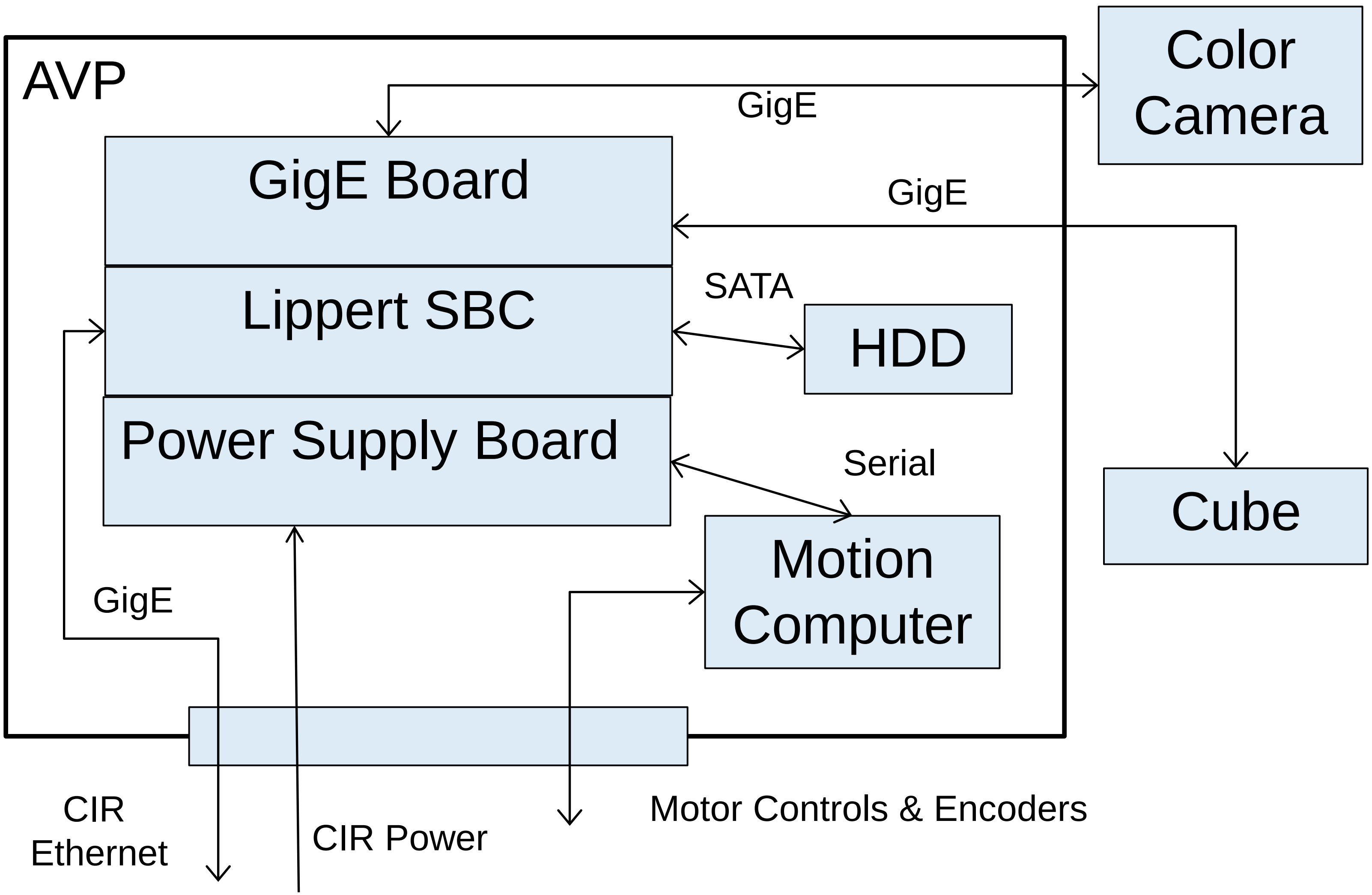


ACME Subsystems

AVP PCIe/104 Stack Concept

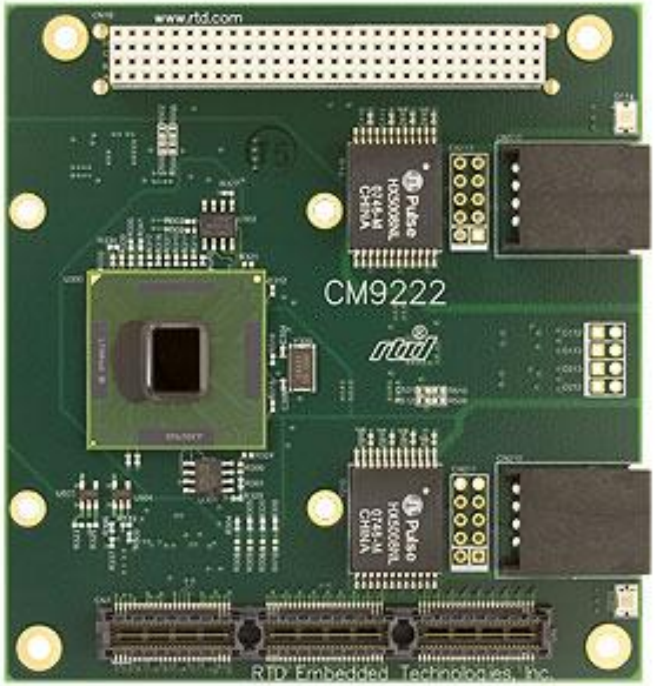


PCI/104-Express Single Board Computer (SBC)

- The SBC is responsible for hosting all flight software
- The SBC for the AVP is the Lippert Cool XpressRunner-GS45
  - Intel 2.26 GHz Core 2 Duo
  - 1 GB DDR3 RAM
  - 2x SATA Ports
  - 8x USB Ports
  - 1x GigE
  - 2x RS-232/485

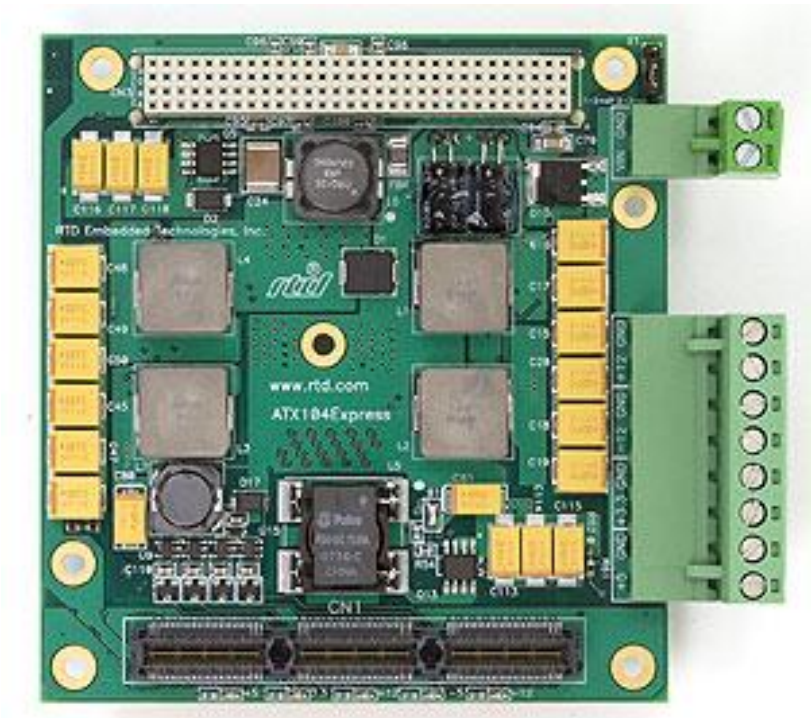
PCIe/104 Gigabit Ethernet Board

- Two Gigabit Ethernet ports



PCIe/104 Power Board

- RTD Embedded Technologies makes an 88W PCIe/104 power supply board (ATX104HR-Express)
- 8-32VDC input
- Powers 5V, 3.3V, 12V on stack



AVP Motion Control Board

- On the stack is the PMD Prodigy PC/104 Motion Board
  - Physically on stack, not on either bus
- One in Camera Package as well
- Handles motion control for servo/stepper motors
- Up to 4 axes per board
  - AVP - TFP array, Igniter
  - Camera – Zoom, Iris, Filters
- Interfaces over RS-232 (serial)

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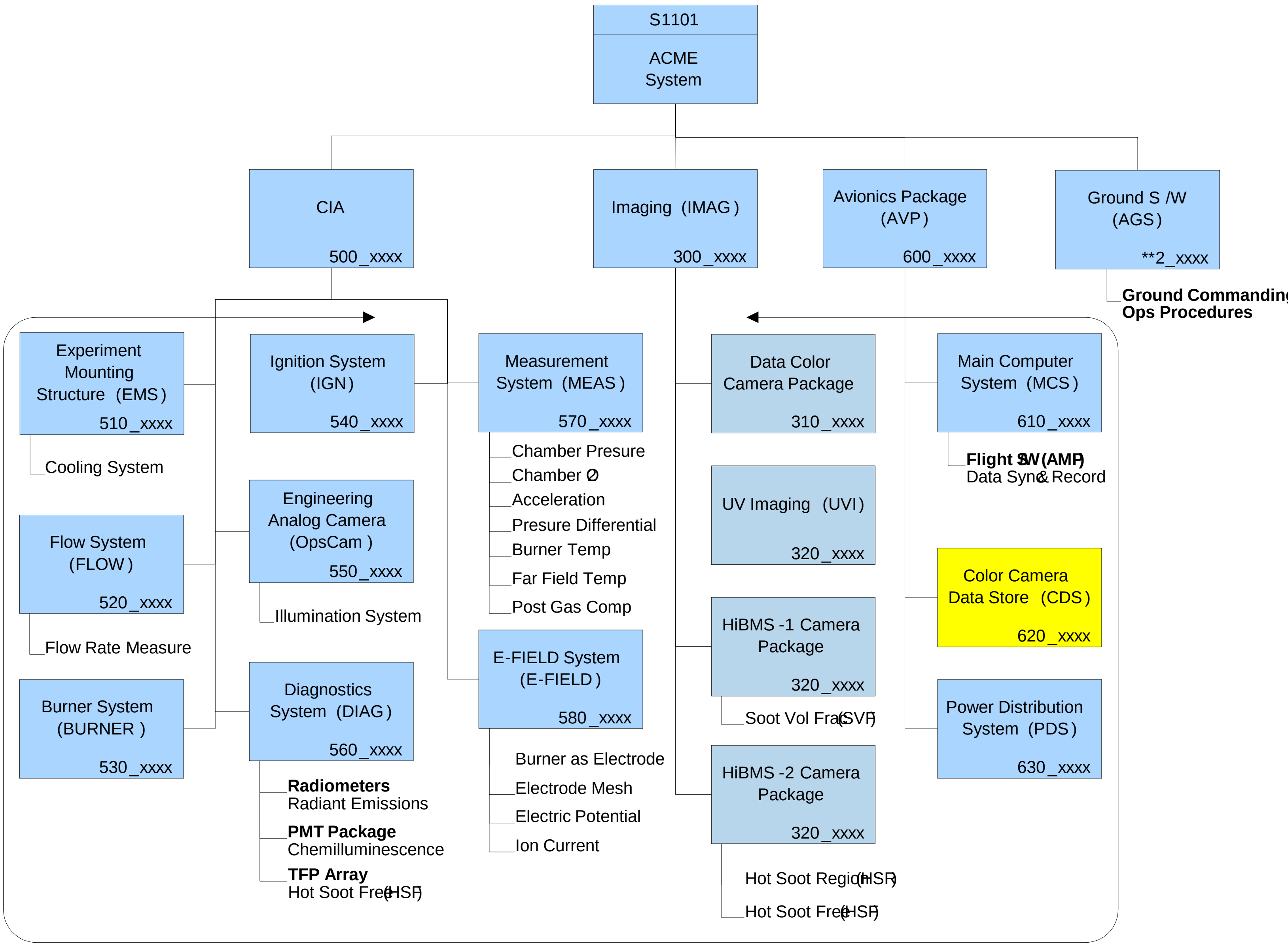


ACME Subsystems

AVP Color Camera Data Storage

- Image storage needs a fast, high capacity hard drive
- WesternDigital Velociraptor 150GB or 300GB
- Tray based design so HDDs are swappable
- 10,000 RPM
- SATAII
- 2.5 inch (small!)

Avionics/Electronics

Tim Gobeli
ACME Electrical Engineering Lead

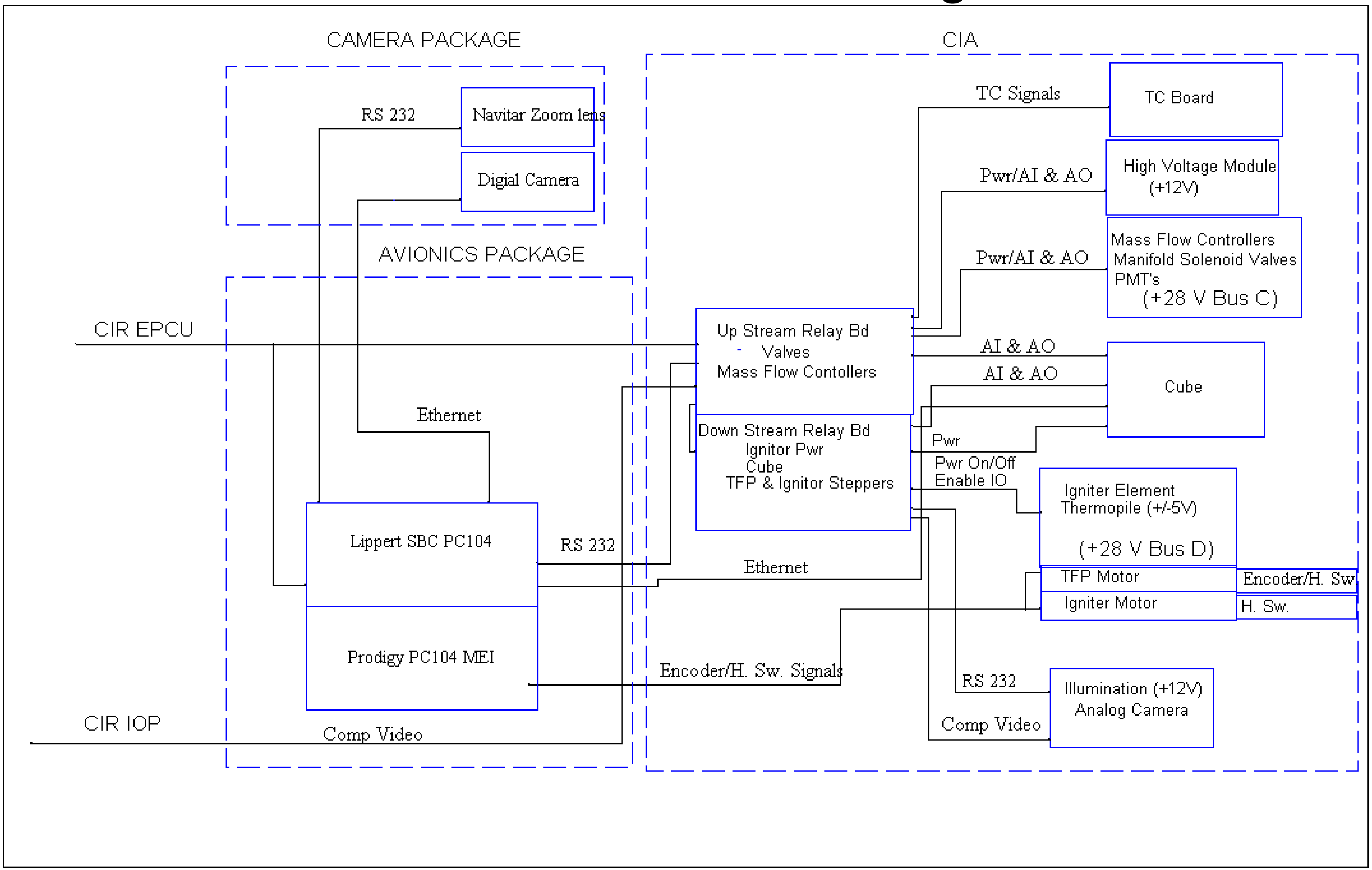
Advanced Combustion via Microgravity Experiments (ACME)

- Cube Analog input (differential inputs) and outputs (single ended) collect experiment telemetry and provide hardware control.

- Analog Outputs
  - D/A Cube +5 – 0 outputs to relay boards provide the discrete I/O channels to chamber – on/off, enable/disable to MFCs, valves, igniters, both stepper drives, illumination, High Voltage and a variable output to control MFC, High Voltage, Photomultiplier gains.

- Analog Inputs
  - Collects Radiometer, Photomultiplier, Gas flow rates, Multiple Temperature points data, Ion Current and High Voltage Grid measurements.

ACME Data and Control Diagram



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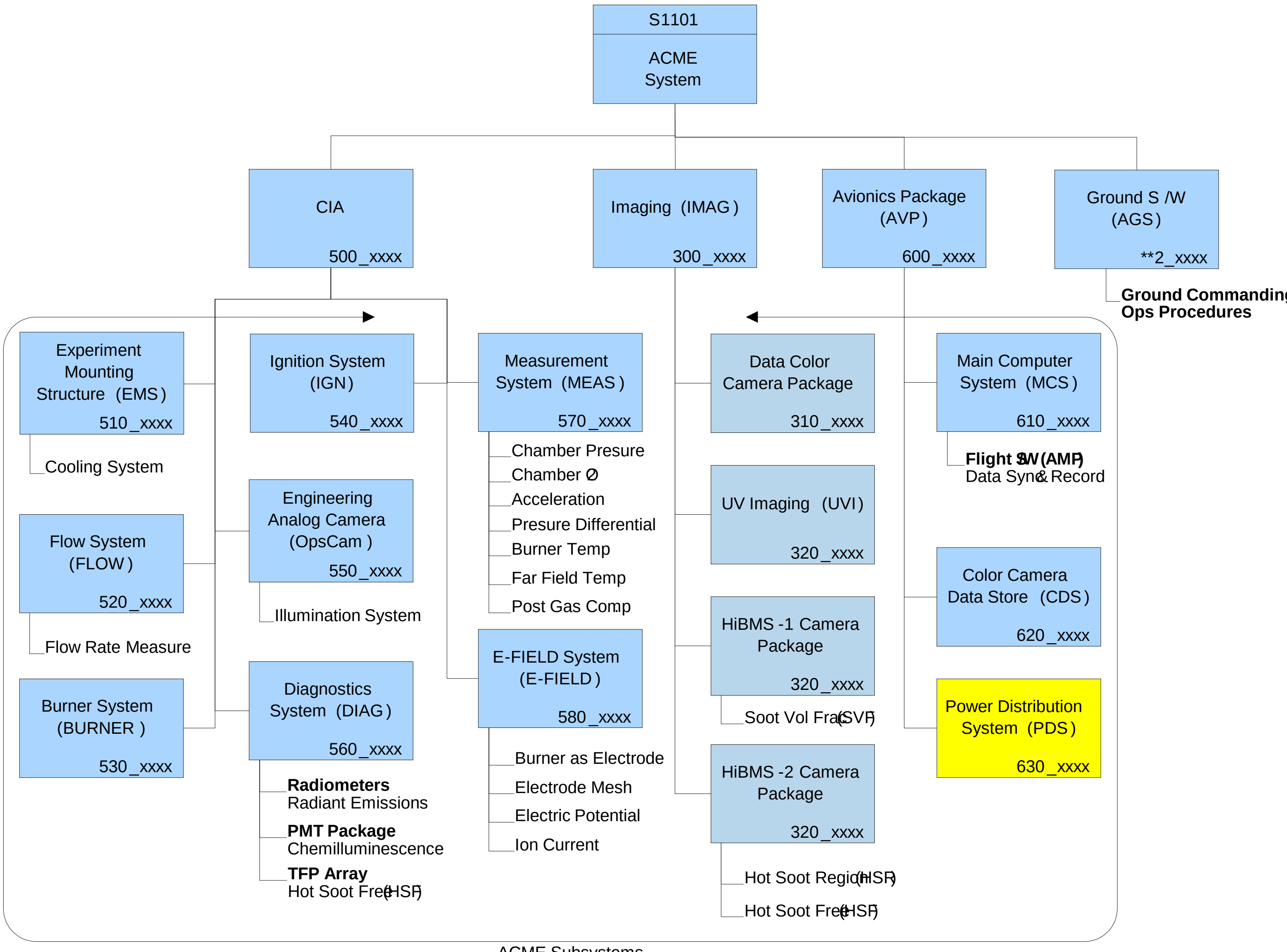
Advanced Combustion via Microgravity Experiments (ACME)



ACME Avionics Package Power Distribution

- Primary power provided by CIR from three 8 amp 28 VDC circuits from PIL connector.

- **Power Board**
- DC/DC converters provide secondary power for:
  - $\underline{+}$5 volt Relay Board (logic side) Photo Multiplier
  - Radiometer Motion Controller Card
  - Hard Driver
  - +12 volt levels
  - Analog Camera
  - Ultravolt High Voltage supply
  - Illumination
  - Hard Drive Single Board Computer

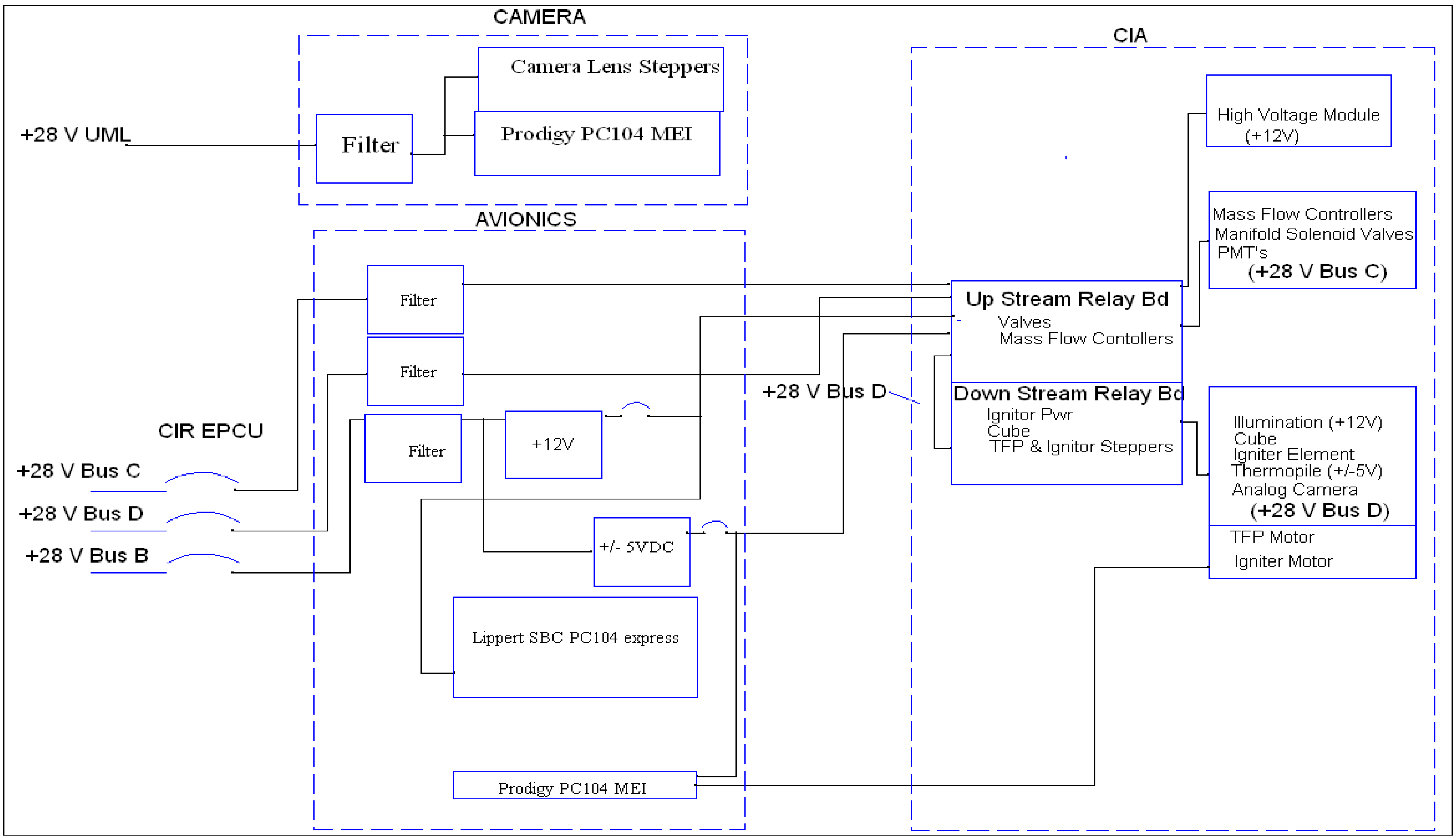
ACME Avionics Package Power Distribution (con't)

- Passes through +28 V EPCU power for SBC, Chamber Insert Motors, Valves, Cube (12.3 watts) – Filters for this power TBD.

- Linear Regulator for voltage level and filtering ripple to mass flow controllers (mfc's) 3 @ 6.15 watts each , regulate 28 volt power to 26 volts. MFC's contain converters of their own, manufacturer will modify to isolate primary side from chassis to maintain single point ground requirement.

- Also will provide power and circuit wire protection to CIA through CIR interconnection cabling from PIL1 and PIL 2 to JCTC5 and JCTC7 respectively

Power System Block Diagram



Bus B

+12 V

HV supplies (2) - .6a ea @ 12V = 1.2 A
Illumination tbd

Analog Camera	.220 amps
hard drive	.3 amps
CPU - 40 watts	3.33 amps

12 volt Current total 4.64amps (Total available 8.3 amps)
Reflected to 28 Volt side (.79 efficiency) = 2.52 Amp

+/-5v

Motion Controller Card = .8A
PMT.062 a @ +/-5V (3) = .186 A
Radiometer +5v .0012 (3) = .0036
Hard drive .95 amps
Relay Board = .13

+/- 5 Volt Current 1.172 (~Total available 10 amps)
Reflected to 28 Volt side (.79 efficiency) = 1.48 amps

Bus B Total Current = 4.8 Amp

Load Calculations

Bus D

Cube +28 V cube			
	ppc5		4.0 watts
	AI-207		2.2 watts max
	AI-225		3.9 watts
	AO-333		3.0 watts
	Subtotal =		13.1 watts @ 28V = .467A
	TFP Stepper	1.4A	
	Igniter Stepper	1.4 A	
	Igniter	2.0 A	
Bus D Total Current		5.267 A	

Bus C

+28 V	Solenoid valves (10) .35A ea =	3.5 A	
MFC (3)	.28A ea = .	.84 A	
Bus C Total Current			4.34 A

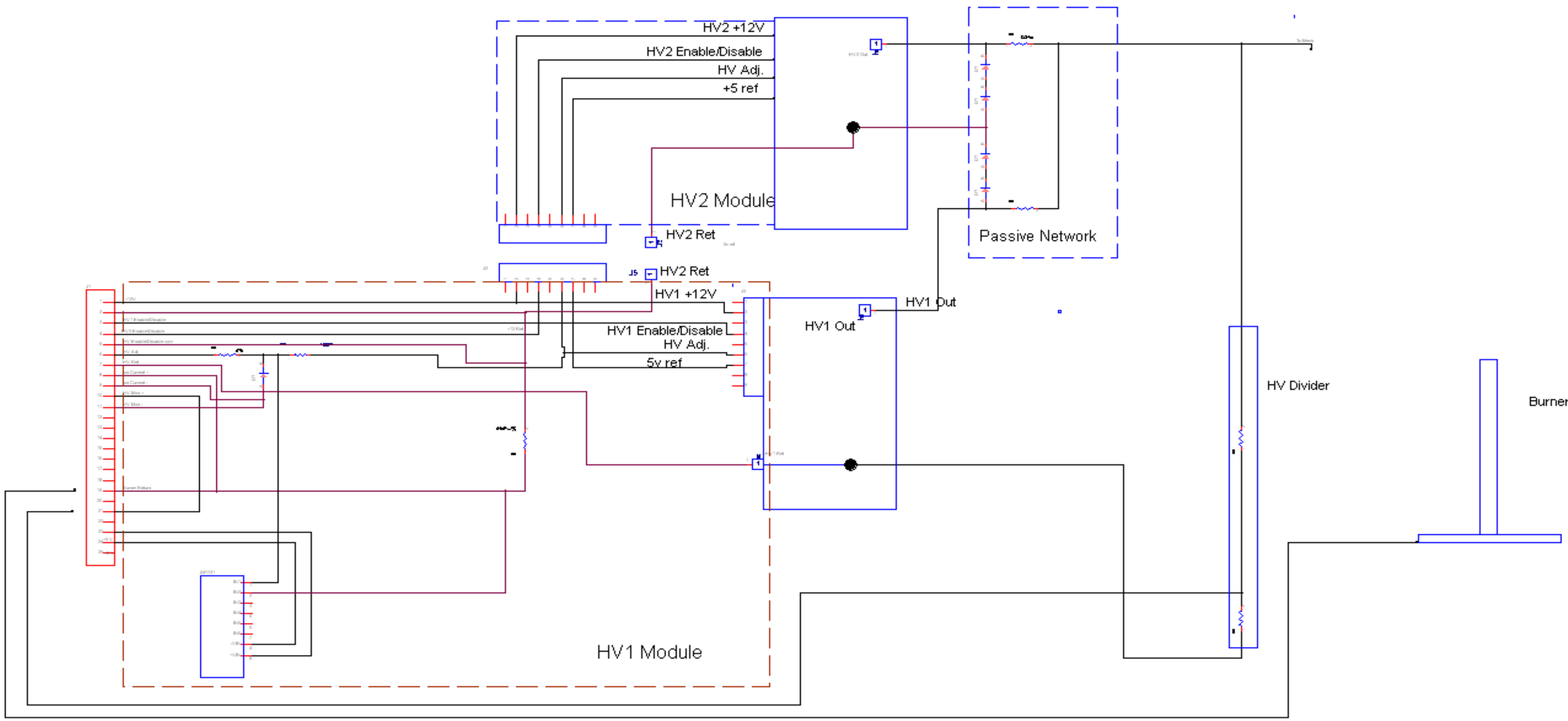
ACME Chamber Insert E Field

- High voltage provided by one positive and one negative voltage output module (Ultravolt 20A series 20KV output).

- Bipolar operation via passive network and superimposing of supplies (no mechanical switching involved) and results in +/- 10KV output.

- Ion current monitored via shunt resistor (arc protection across shunt will be implemented)

ACME E-Field Circuitry Diagram

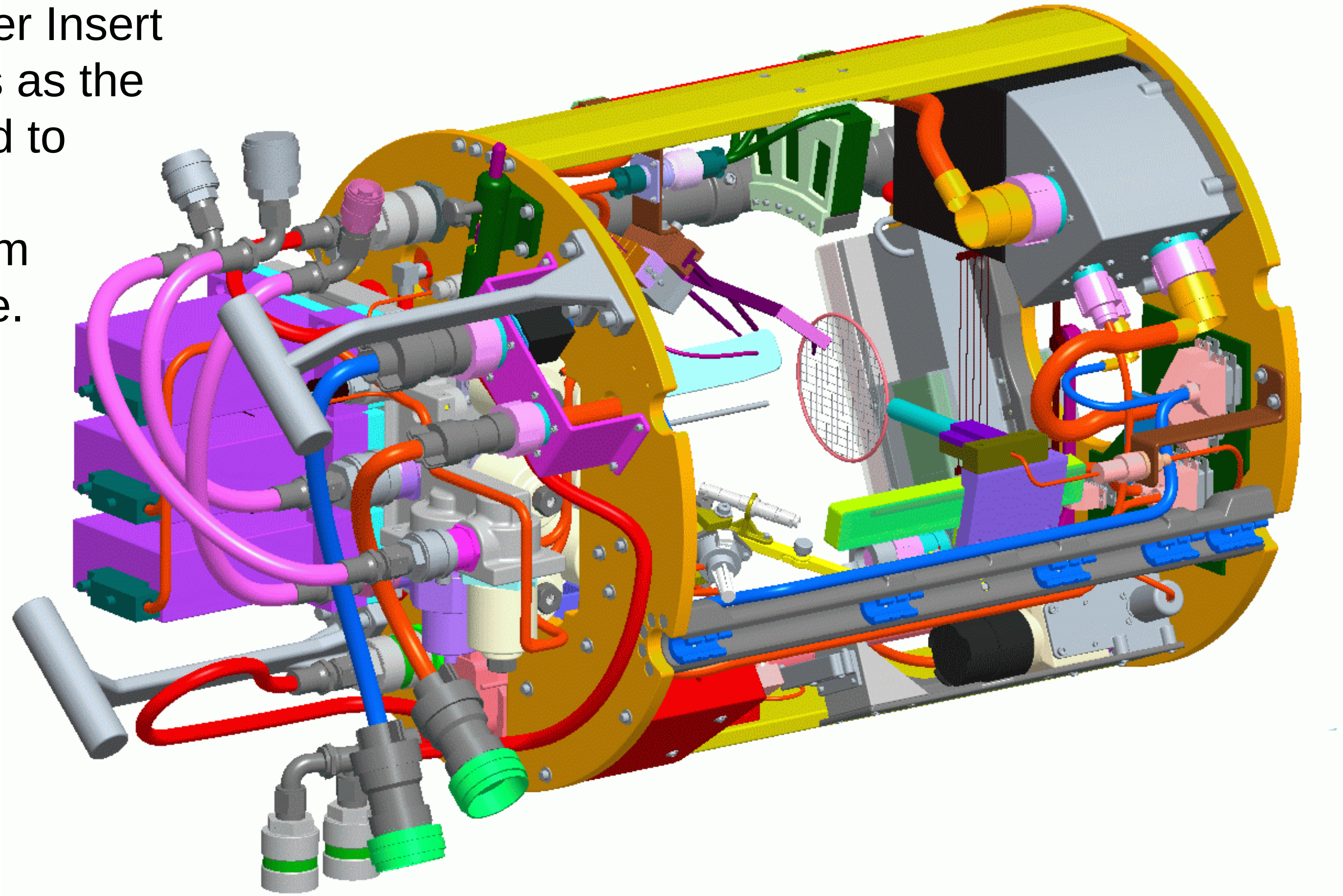


Chamber Insert Assembly (CIA) Designs

Adrian Drake
ACME Mechanical Engineering Lead

ACME Chamber Insert Assembly

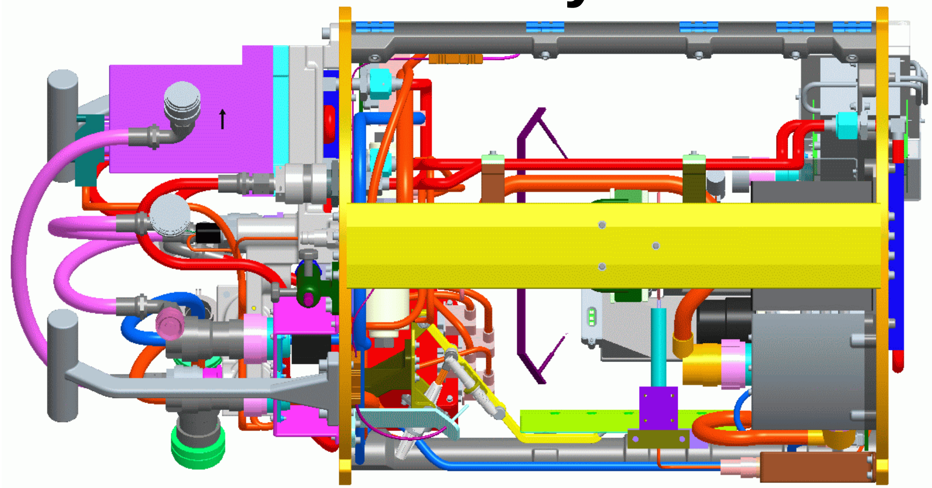
The ACME Chamber Insert Assembly functions as the major platform used to mount Sub-System Hardware to perform combustion science.

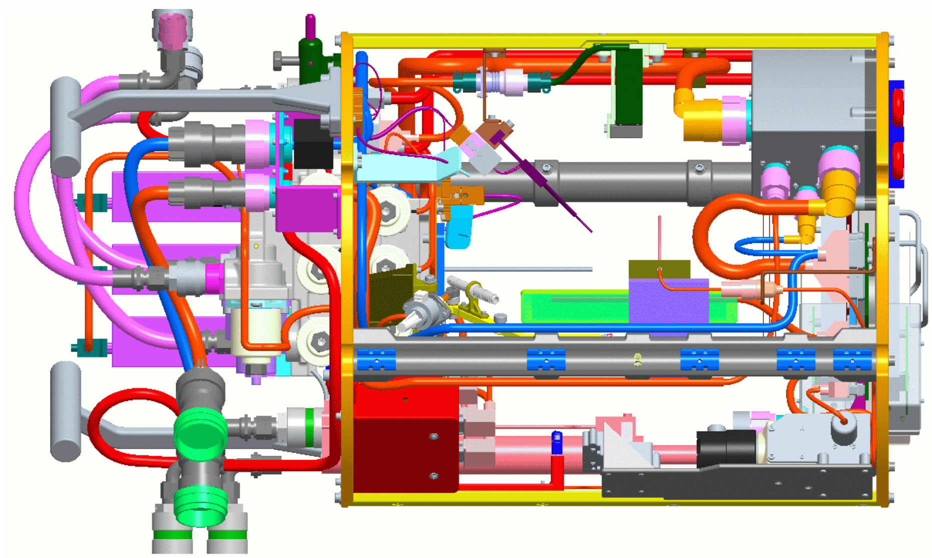


ACME Chamber Insert Assembly

- Component placement maximizes open volume at and downstream of the chamber window interface to satisfy open volume requirements

- Creates mass symmetry where possible per requirements





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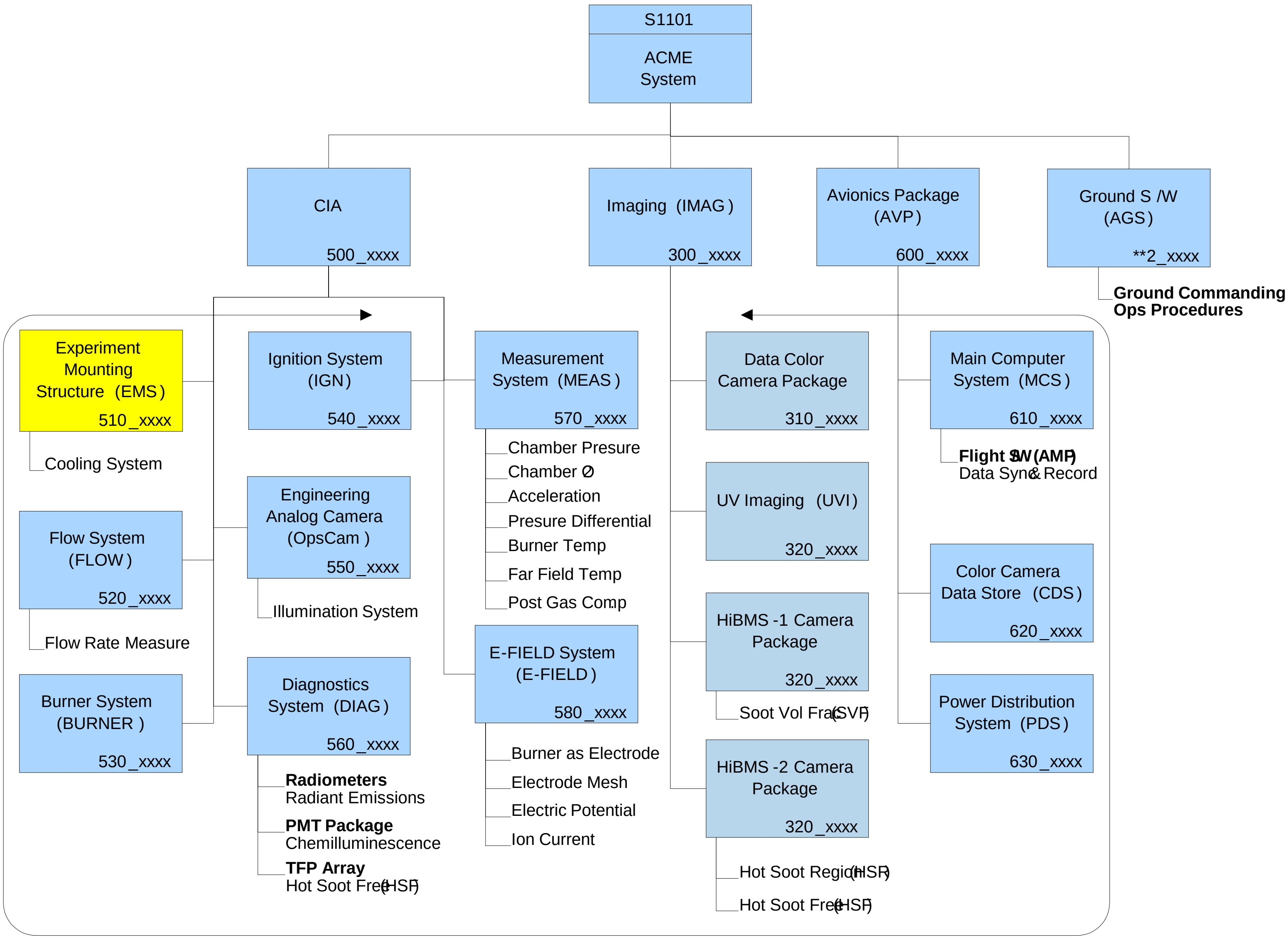
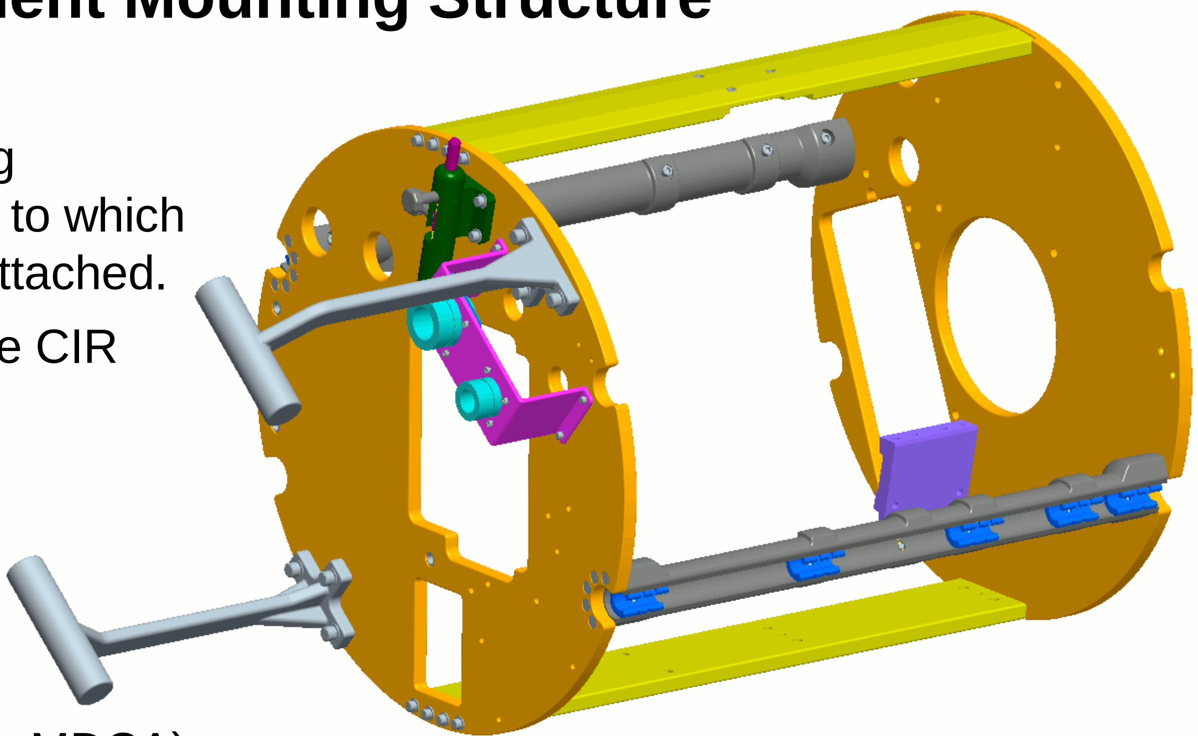


ACME Subsystems

ACME Chamber Insert Assembly
Experiment Mounting Structure

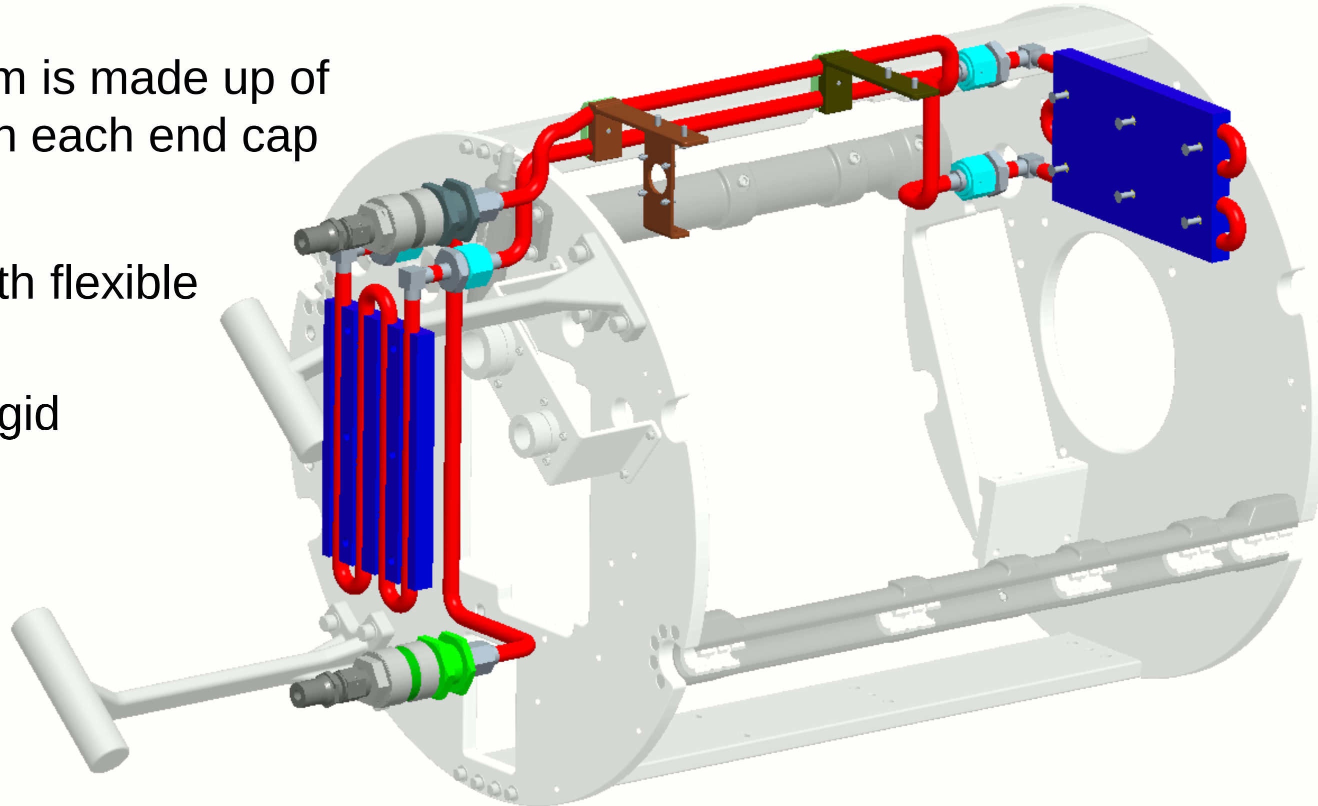


- The Experiment Mounting Structure is the framework to which all other subsystems are attached.
- Aligns the insert within the CIR Chamber

It consists of:
- 2 End Plates
- Frame Rails
- Locking Mechanism (from MDCA)
- Insertion Handles
- Component mounting brackets

ACME Chamber Insert Assembly
Cooling System

- The Cooling system is made up of 2 cold plates, one on each end cap
- Lytron CP-10
- Attaches to IRR with flexible hoses
- Internal tubing is rigid



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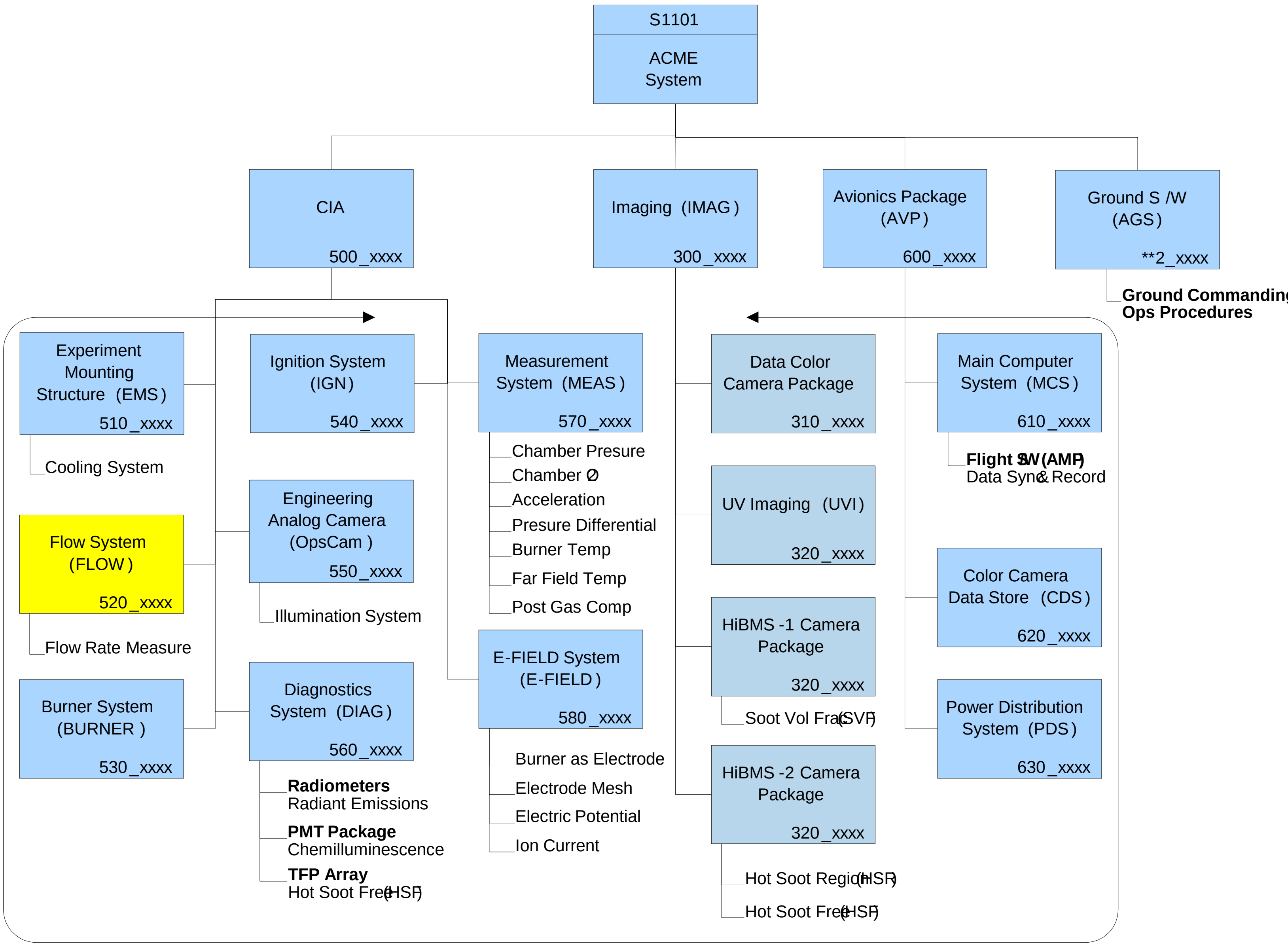
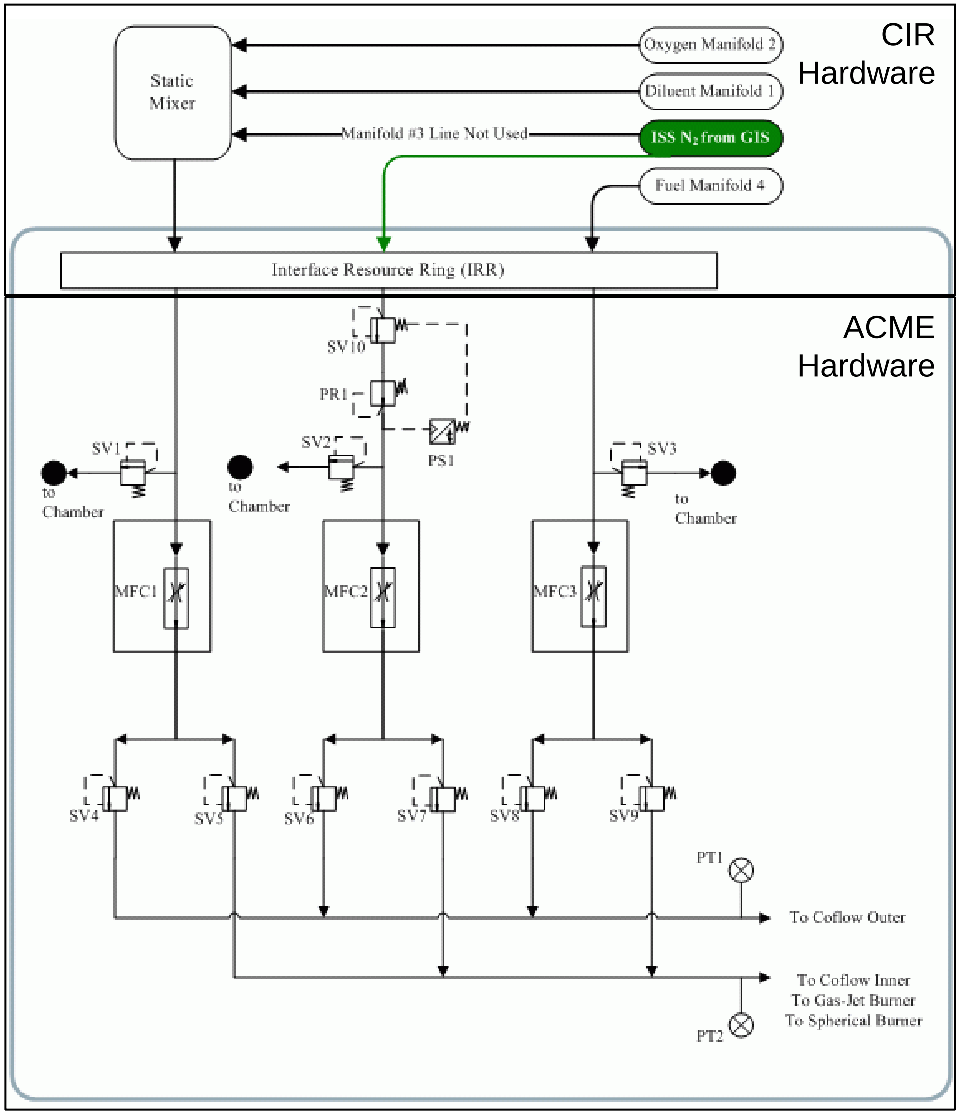


ACME Subsystems

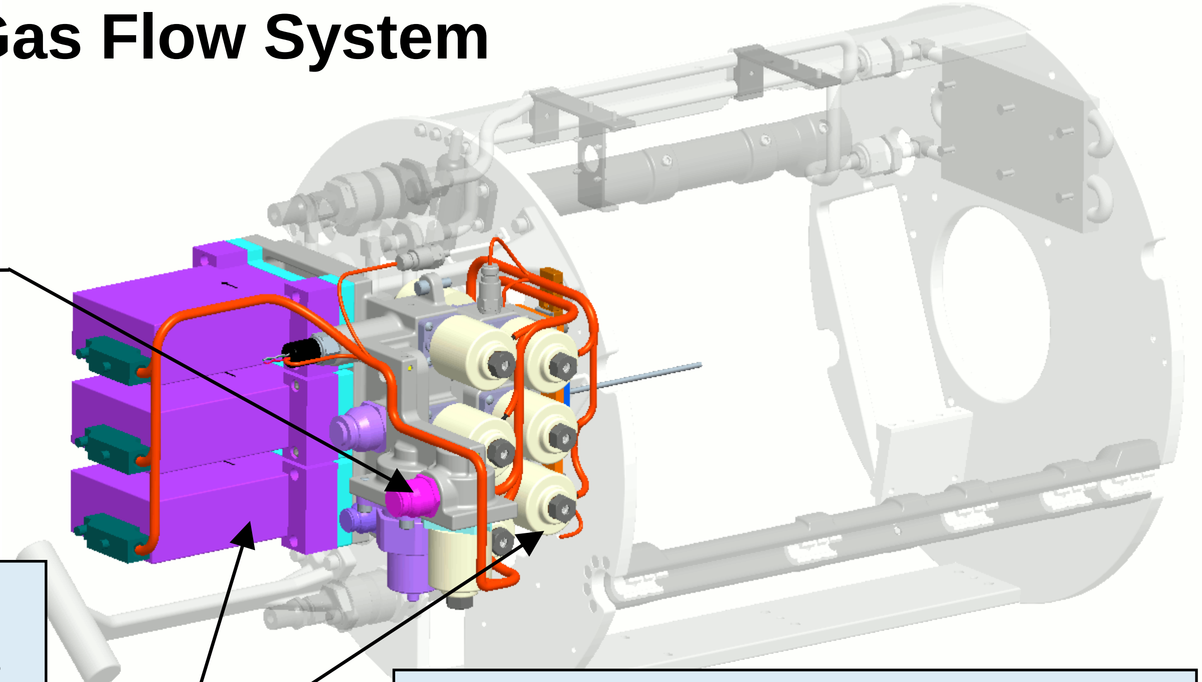
ACME Chamber Insert Assembly

Gas Flow System

- Receives CIR supplied and regulated gases from FOMA
- Provides pressure regulation of gas from nitrogen bypass line to replace those features bypassed on CIR
- Routes gases to the chamber for chamber fills, bypassing the burner
- Meters gas flow via Mass Flow Controllers
- Mixes gases as required
- Delivers gases to the burner



ACME Chamber Insert Assembly
Gas Flow System



IRR QD hookup
- Interface with FOMA

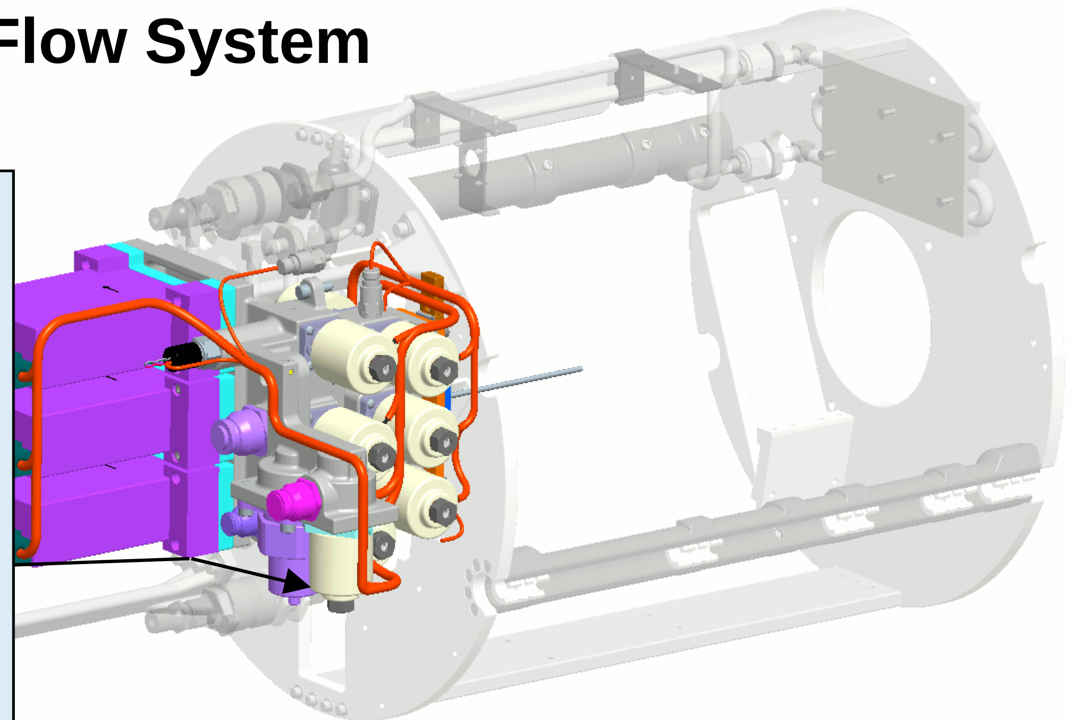
Mass Flow Controllers
- Hastings HFC-D-302 Series
- ORU Replaceable based on experiment
- Sufficient flexibility to meet all experiment requirements

Chamber Vent Valves
- Skinner 7000 Series Low Pressure Solenoid Operated Valves and Lisk L-7040 Solenoid Coil
- Used to bypass the Mass Flow Controllers and burner for faster chamber filling

ACME Chamber Insert Assembly
Gas Flow System

Pressure Regulator Manifold System
- Tescom 44.2269-CM-1-1408 Pressure Regulator
- Klixon 6PS301 Series Pressure Switch
- Skinner 7000 Series High Pressure Solenoid Operated Valve
- Lisk L-7040 Solenoid Coil

- Allows for gas bottle use on Nitrogen Manifold instead of Station Nitrogen
- Replaces safety controls bypassed on the Nitrogen Manifold

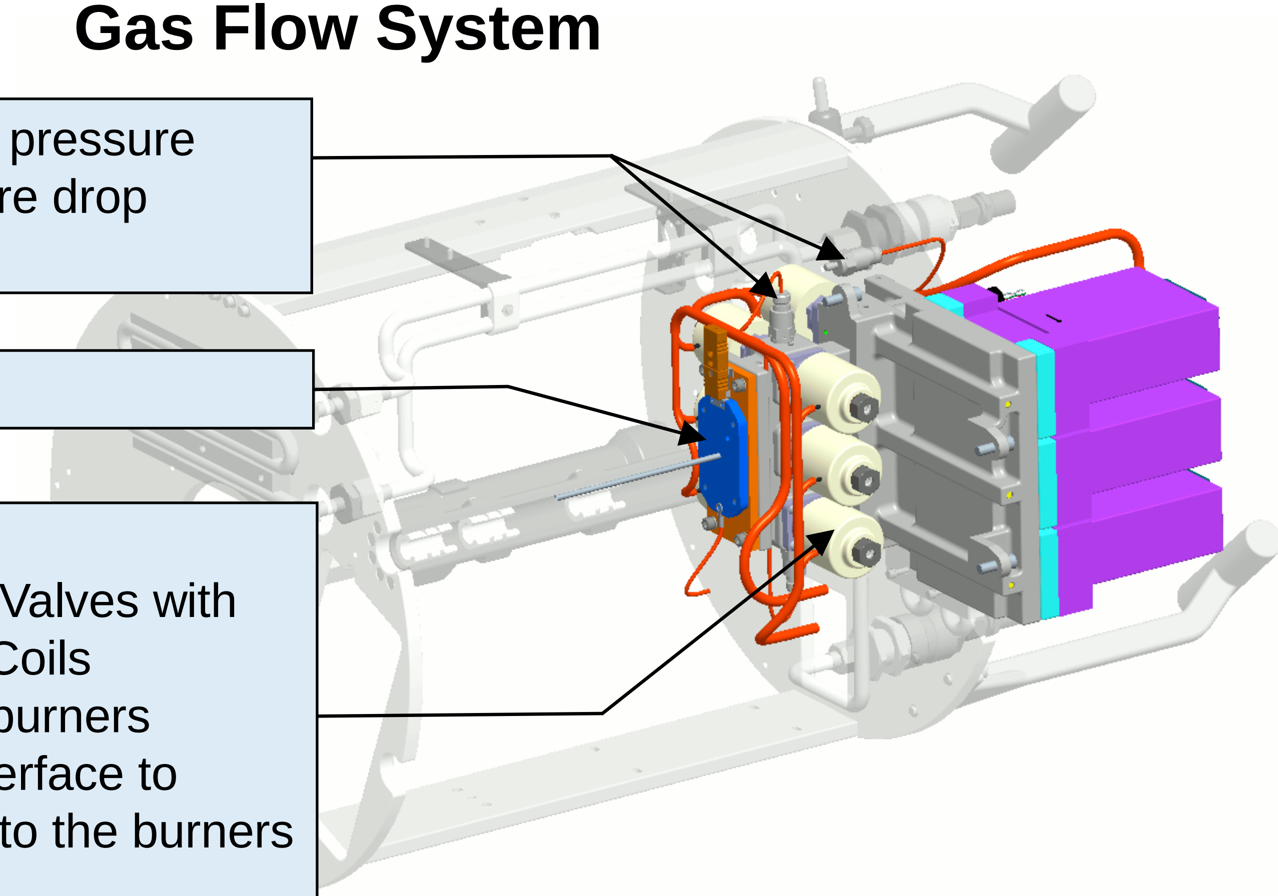


ACME Chamber Insert Assembly
Gas Flow System

Entran EPRB-2 Series pressure transducers for pressure drop calculation

Replaceable burner

Flow Switching Valves
• Skinner 7000 Series Valves with Lisk L-7040 Solenoid Coils
• Controls gas flow to burners
• Requires no crew interface to modify gas flow paths to the burners for each experiment



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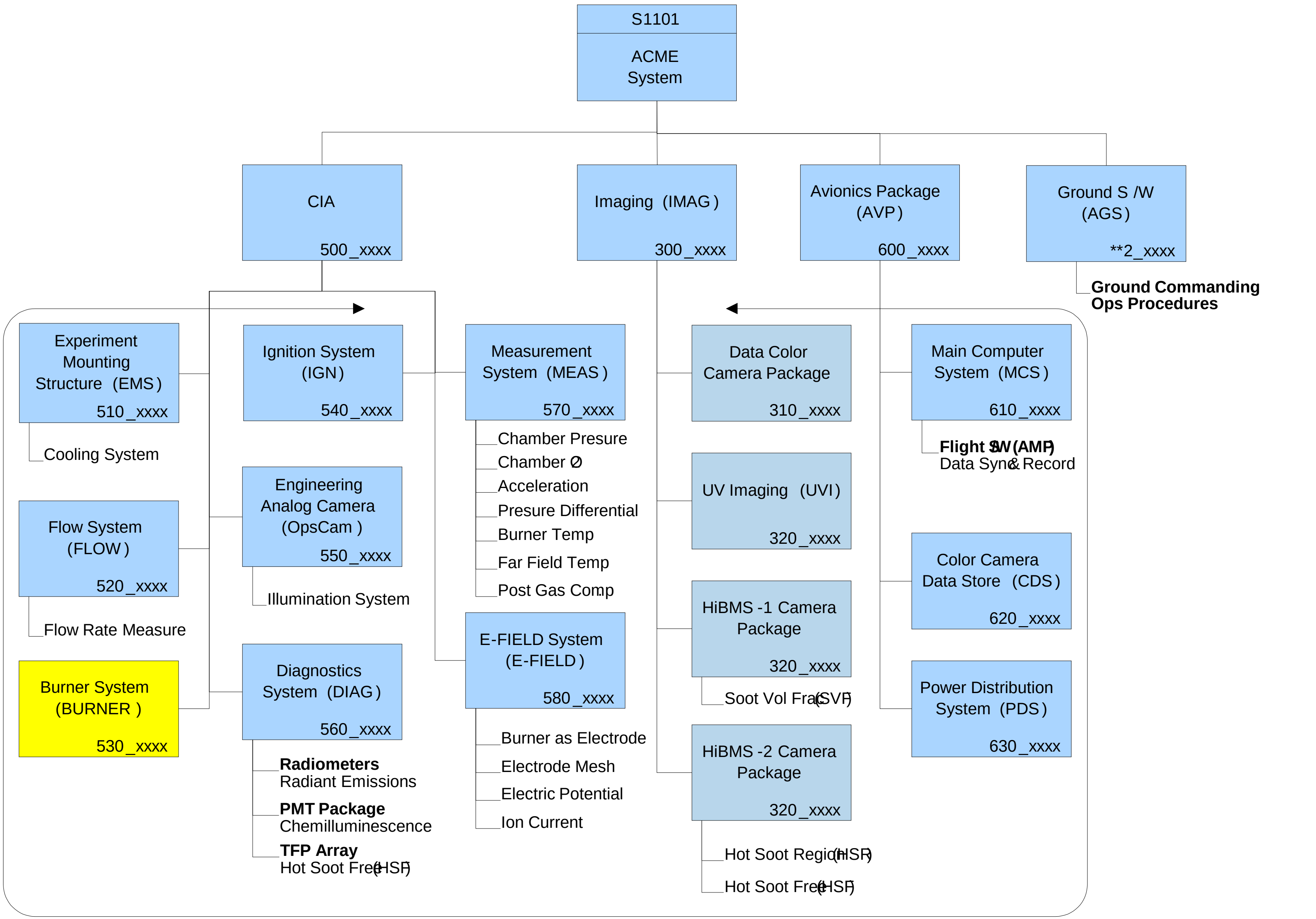


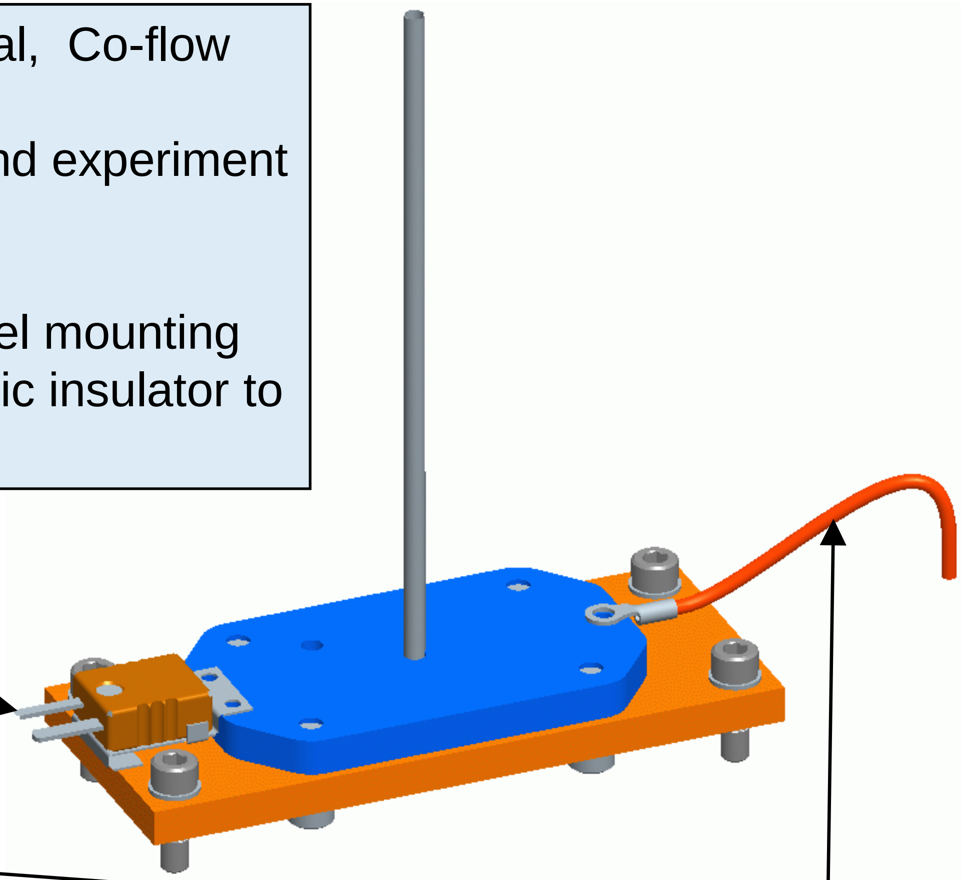
ACME Subsystems

ACME Chamber Insert Assembly
Burner Assembly

Three Burner types, Gas Jet, Spherical, Co-flow

Burners are ORU per requirements and experiment setup

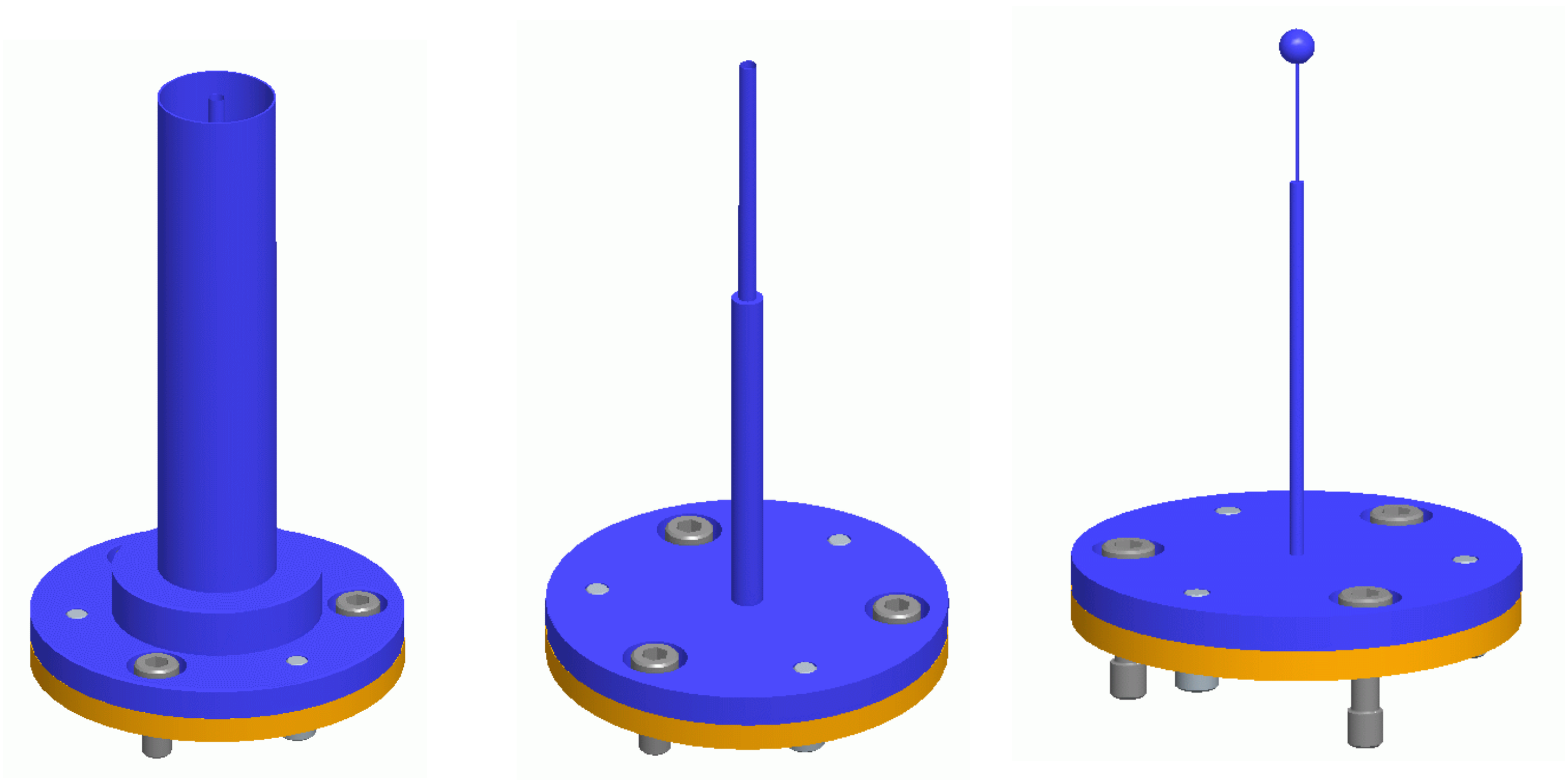
Construction is a burner fixed to a steel mounting plate, which is in turn fixed to a ceramic insulator to isolate the burner electrically



Burner temperature thermocouple connection

E-field measurement attachment

ACME Chamber Insert Assembly
Gas Burner System



Examples of 3 Burner Types

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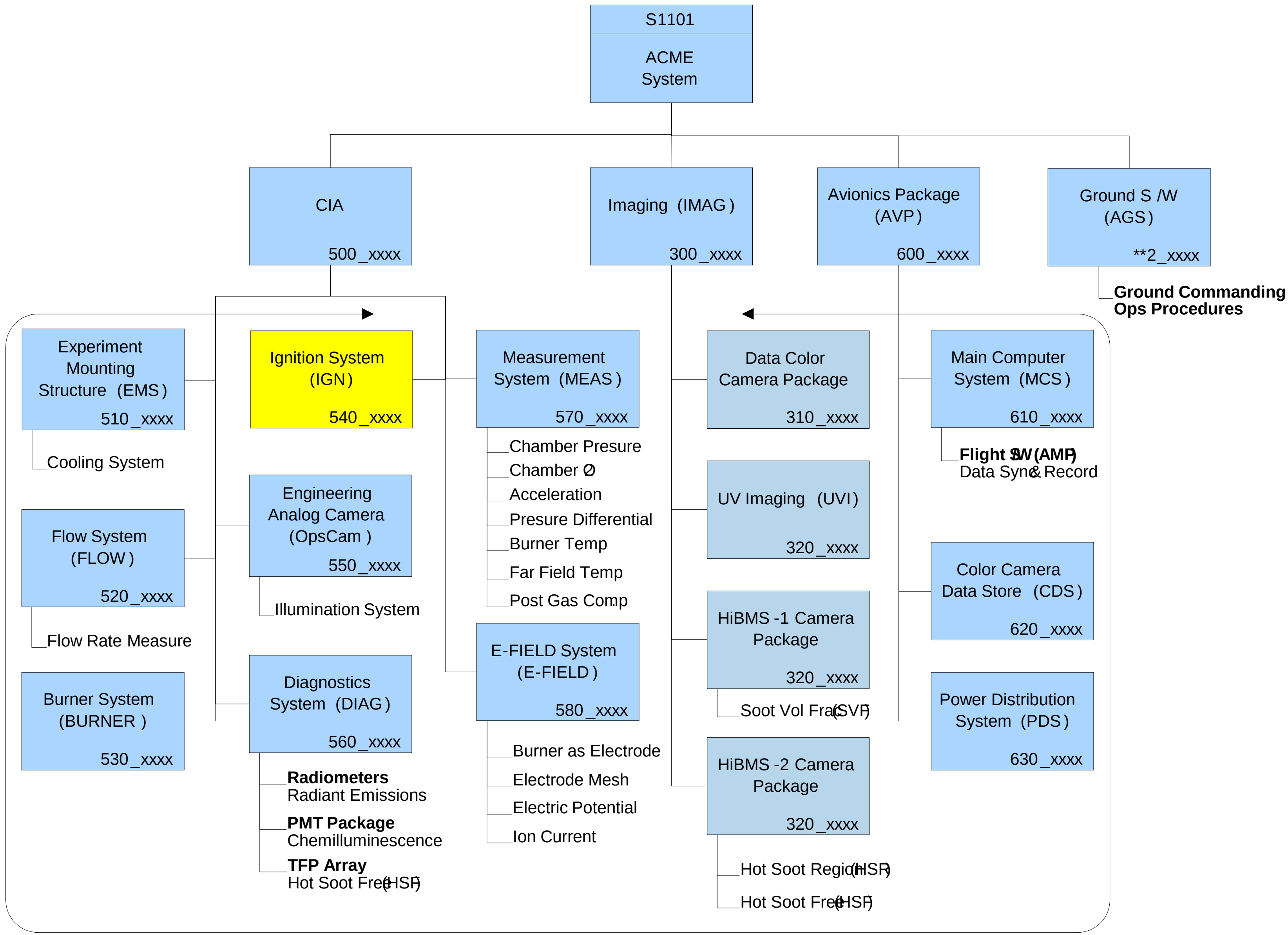
Advanced Combustion via Microgravity Experiments (ACME)

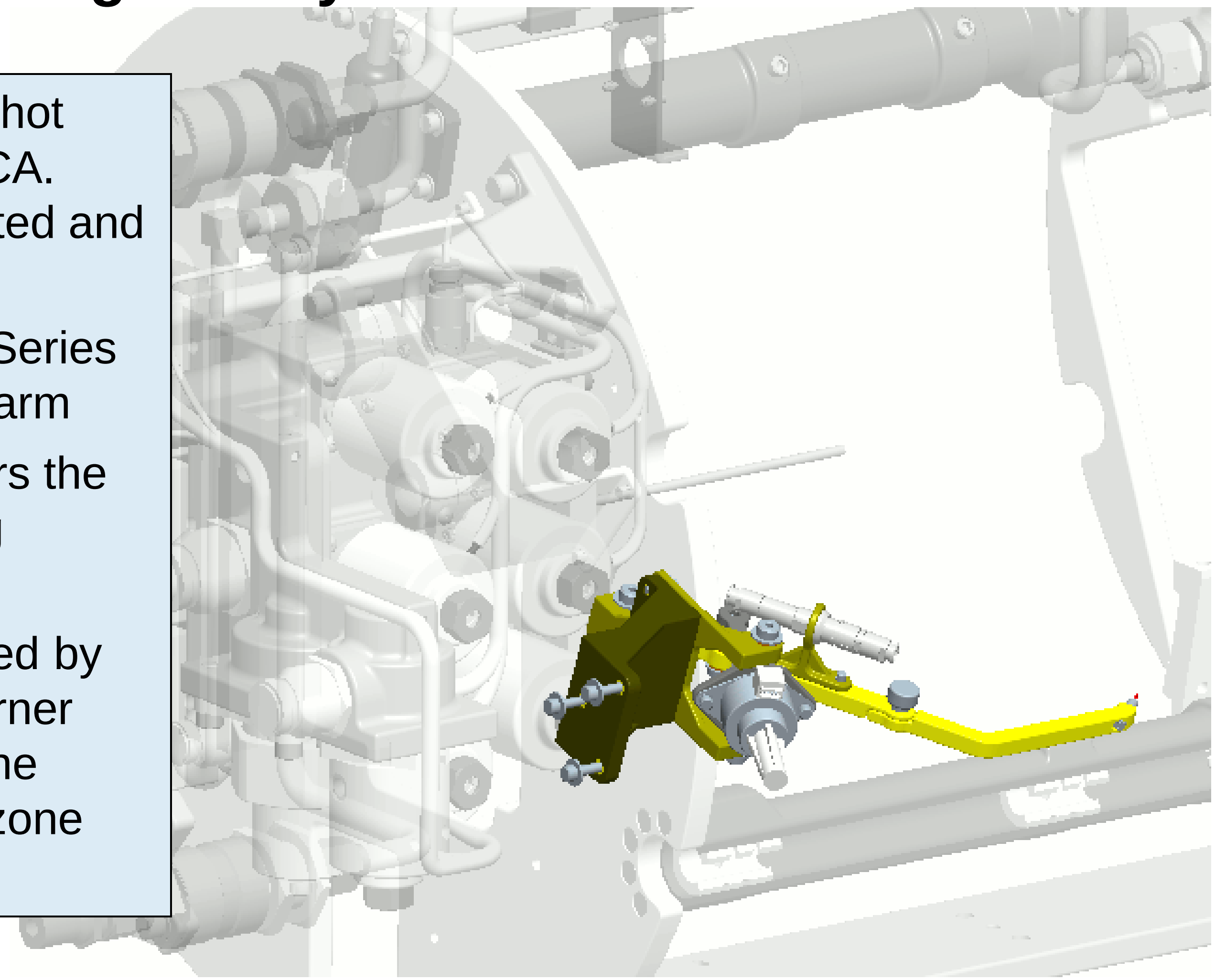


ACME Subsystems

ACME Chamber Insert Assembly

Igniter System

- ACME will use the same hot wire igniter design as MDCA. The concept has been tested and can ignite gaseous flow
- Haydon-Kerk G4 25000 Series Stepper Motor moves the arm
- Pivoting arm design clears the burner tip while minimizing rotation effects
- Igniter tips will be swapped by the crew depending on burner type and size to relocate the igniter tip into the ignition zone



Advanced Combustion via Microgravity Experiments (ACME)

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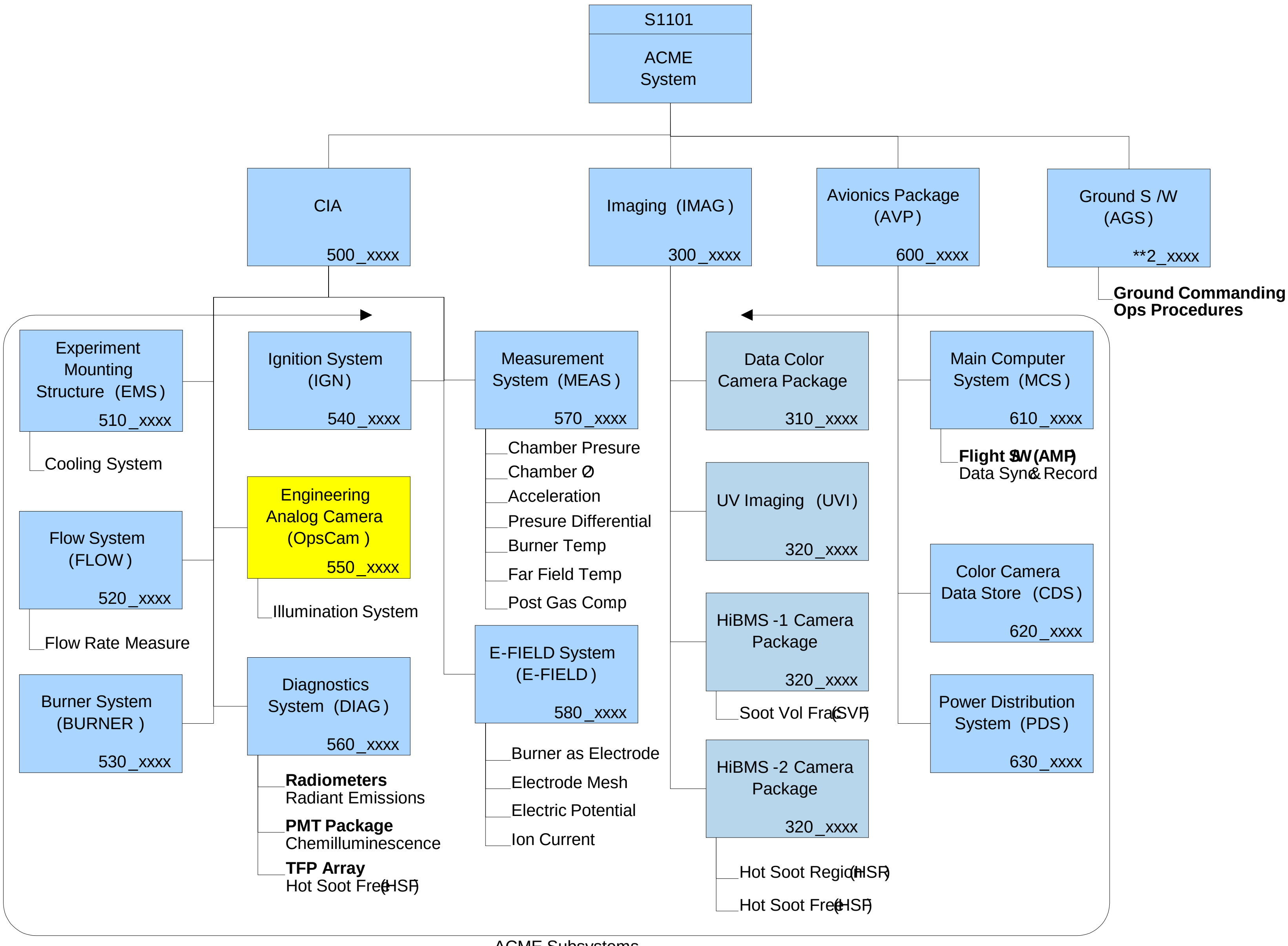
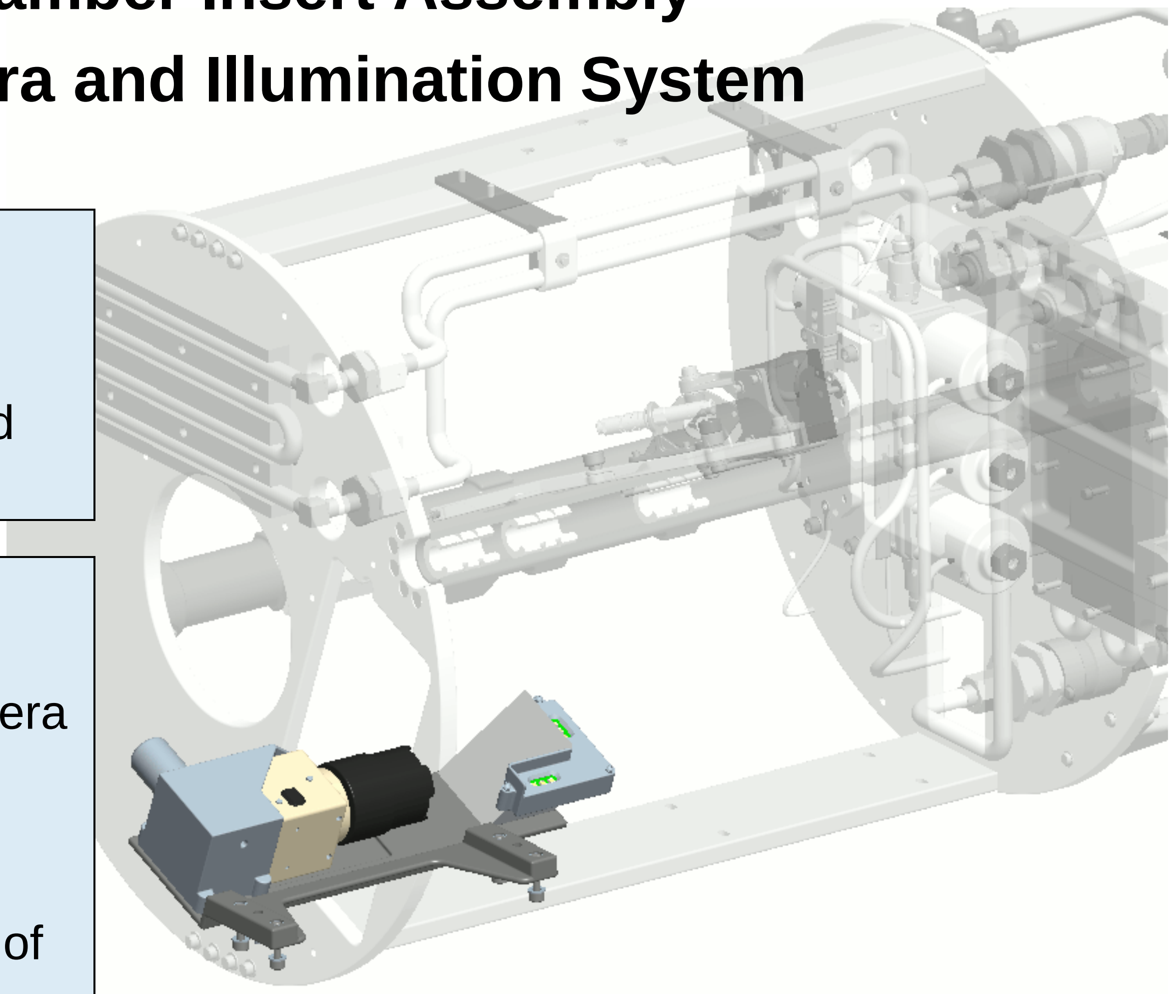


ACME Chamber Insert Assembly
Analog Camera and Illumination System

The Analog Camera System satisfies requirements for near real-time visual information regarding experiment setup and progress.

The System consists of:

• Hitachi KP-D20B Analog Camera
• 45 degree turning mirror
• Two banks of LEDs for illumination with adjustable intensity to minimize saturation of diagnostic sensors



Advanced Combustion via Microgravity Experiments (ACME)

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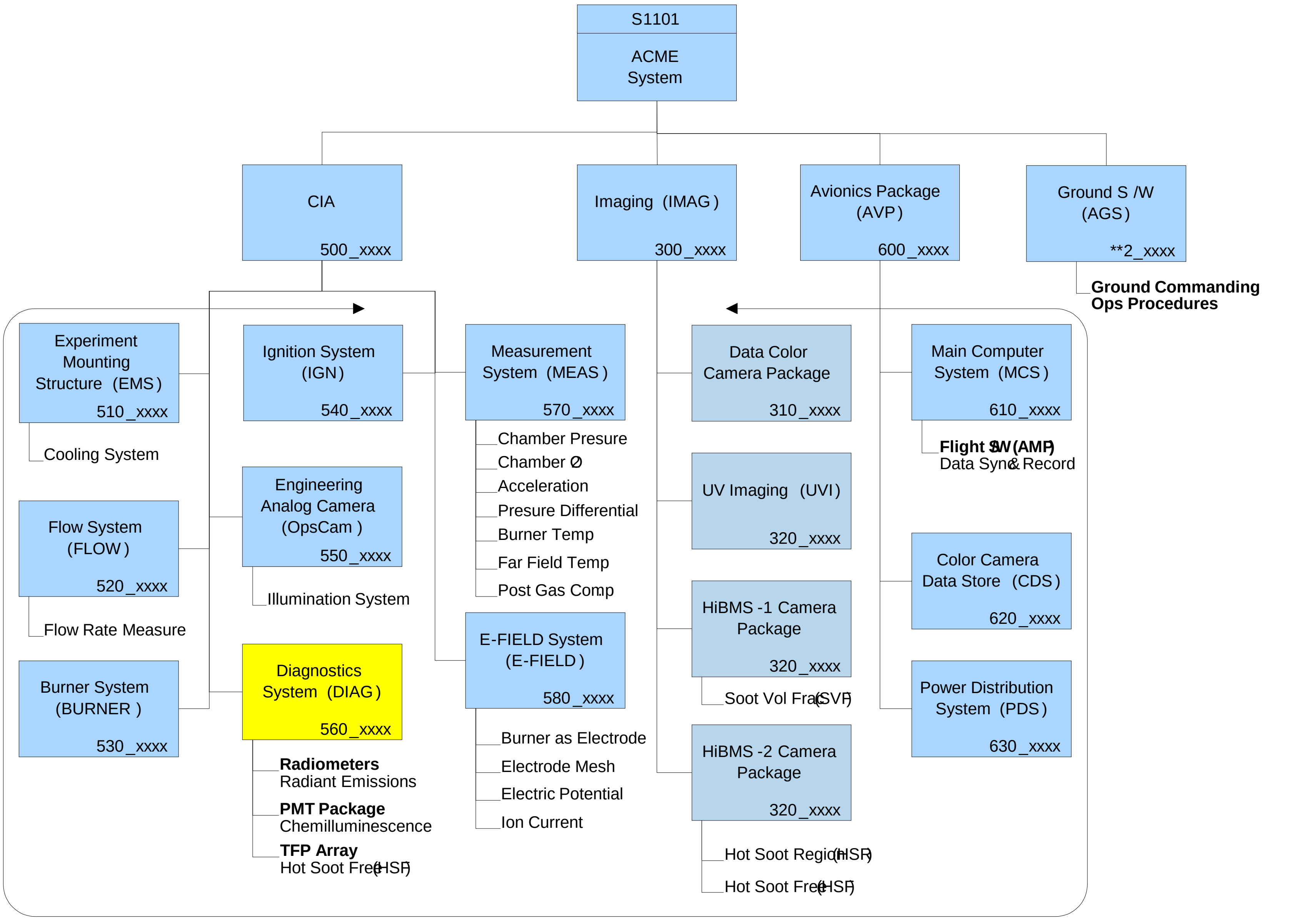


ACME Subsystems

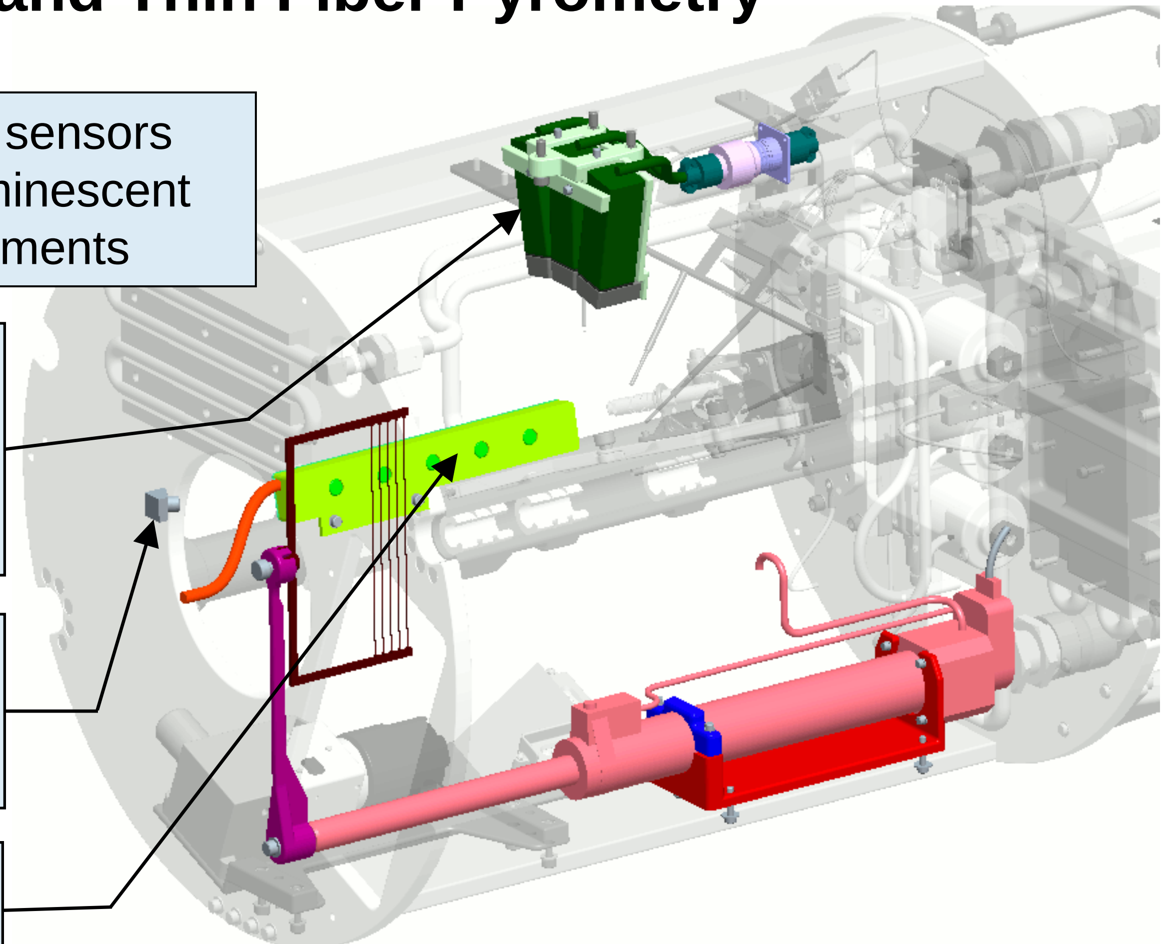
ACME Chamber Insert Assembly Diagnostics and Thin Fiber Pyrometry

The Diagnostic system includes sensors used for radiative and chemoluminescent emissions measurement requirements

ORU PMT Array, made of 3 individual Hamamatsu H10722-110 D Photomultiplier Tubes

1 Dexter ST-150 Radiometer offset at 60 degrees to the chamber axis

5 Dexter 2M Radiometers in a linear array

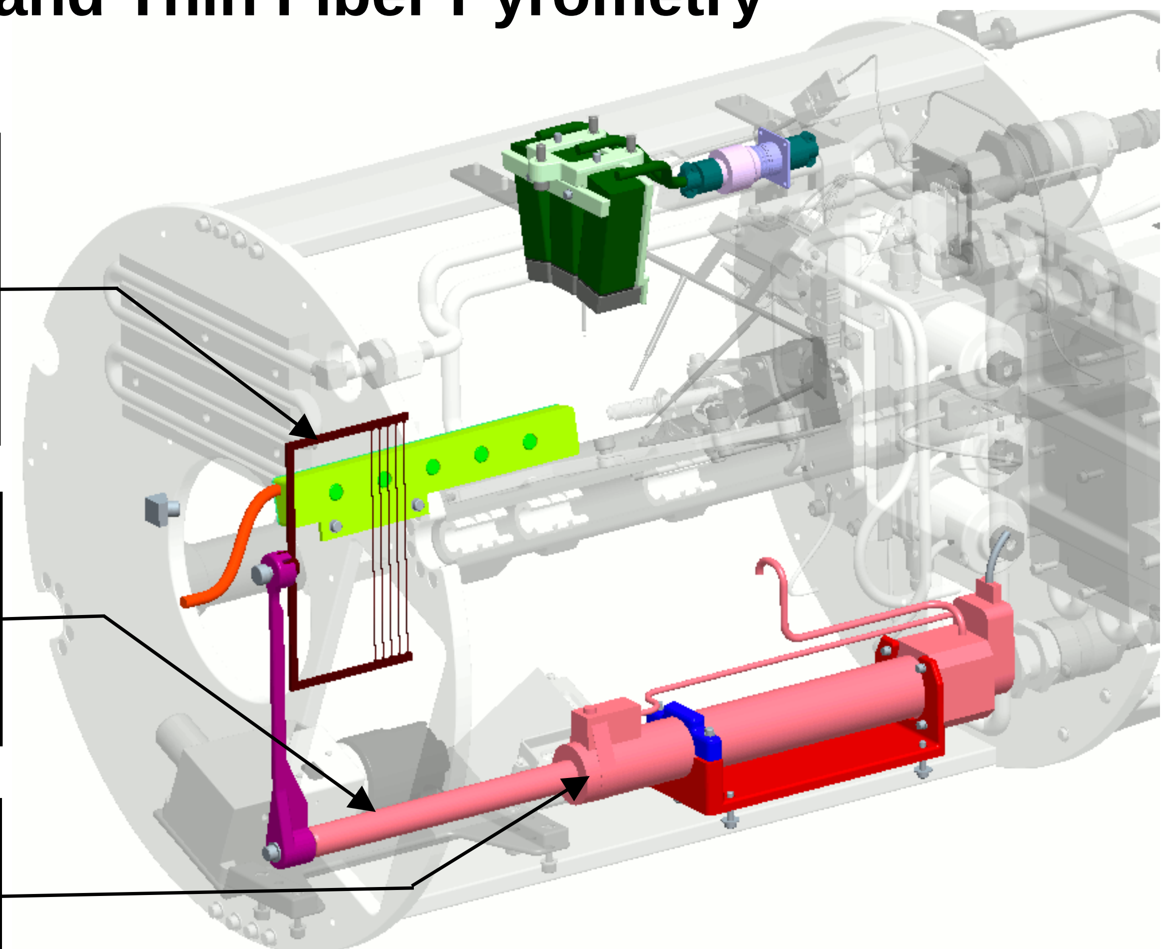


ACME Chamber Insert Assembly
Diagnostics and Thin Fiber Pyrometry

The Fiber Array itself is ORU in case of damage or wear, and can be rotated to position it to face either the Color Camera or the HiBMS-2

The Array translates out of the field of view when not needed and can be adjusted to any position within the flame

The TFP Motor is an Ultramotion Digit HT17 Series stepper motor



Advanced Combustion via Microgravity Experiments (ACME)

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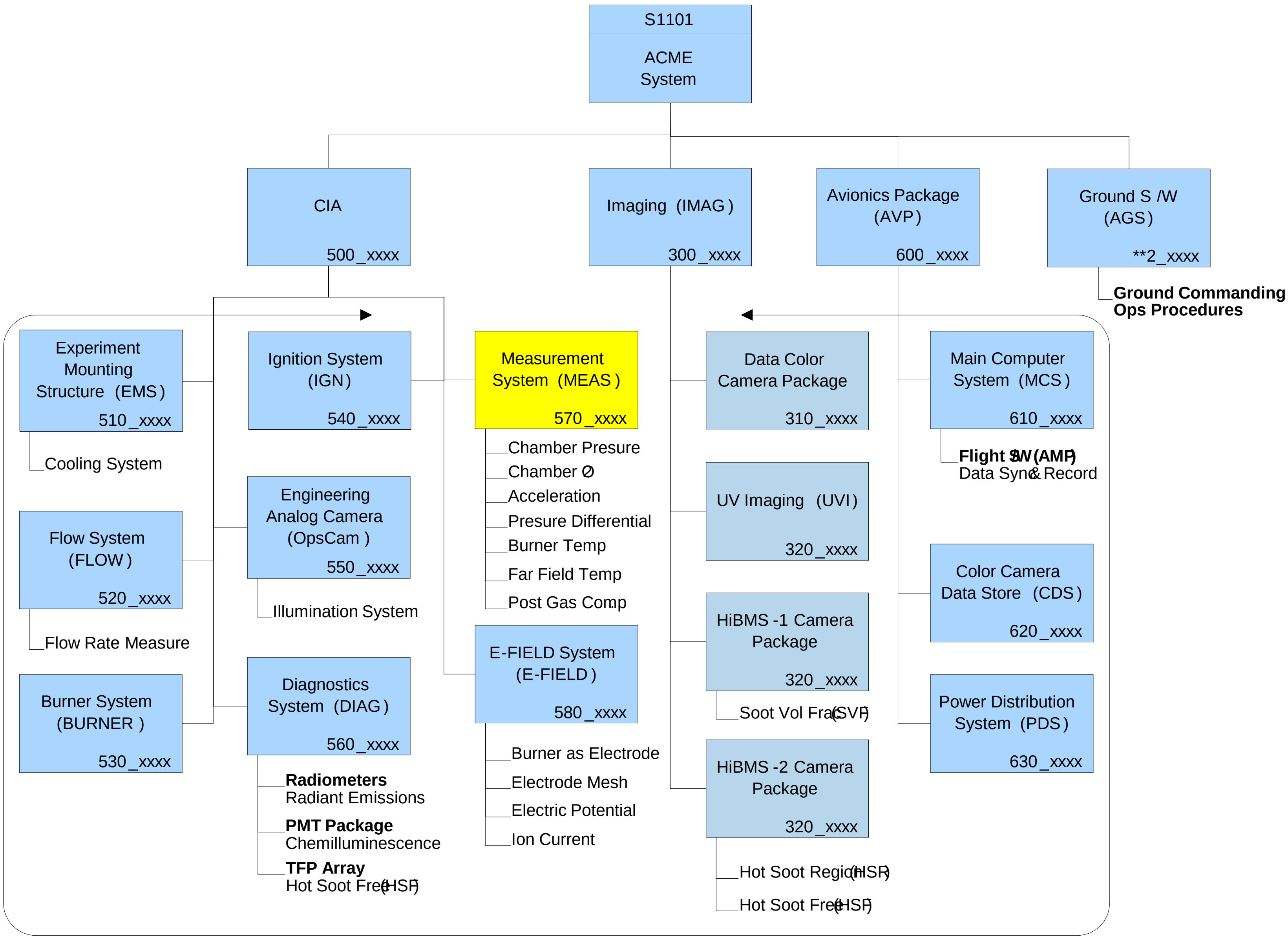


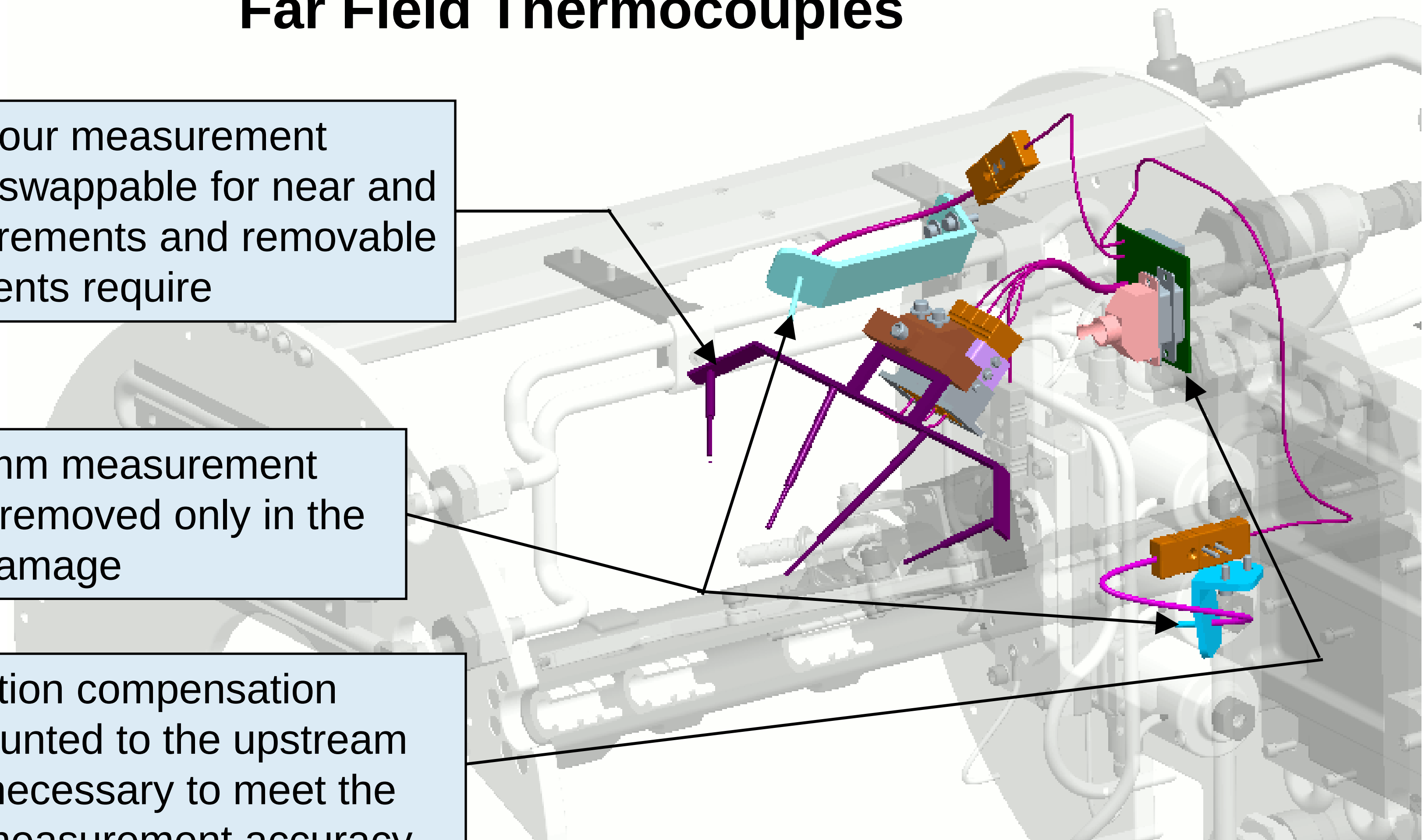
ACME Subsystems

ACME Chamber Insert Assembly
Far Field Thermocouples

A rake of four measurement positions, swappable for near and far measurements and removable if experiments require

Two 200mm measurement positions, removed only in the event of damage

Cold Junction compensation board, mounted to the upstream end cap, necessary to meet the required measurement accuracy

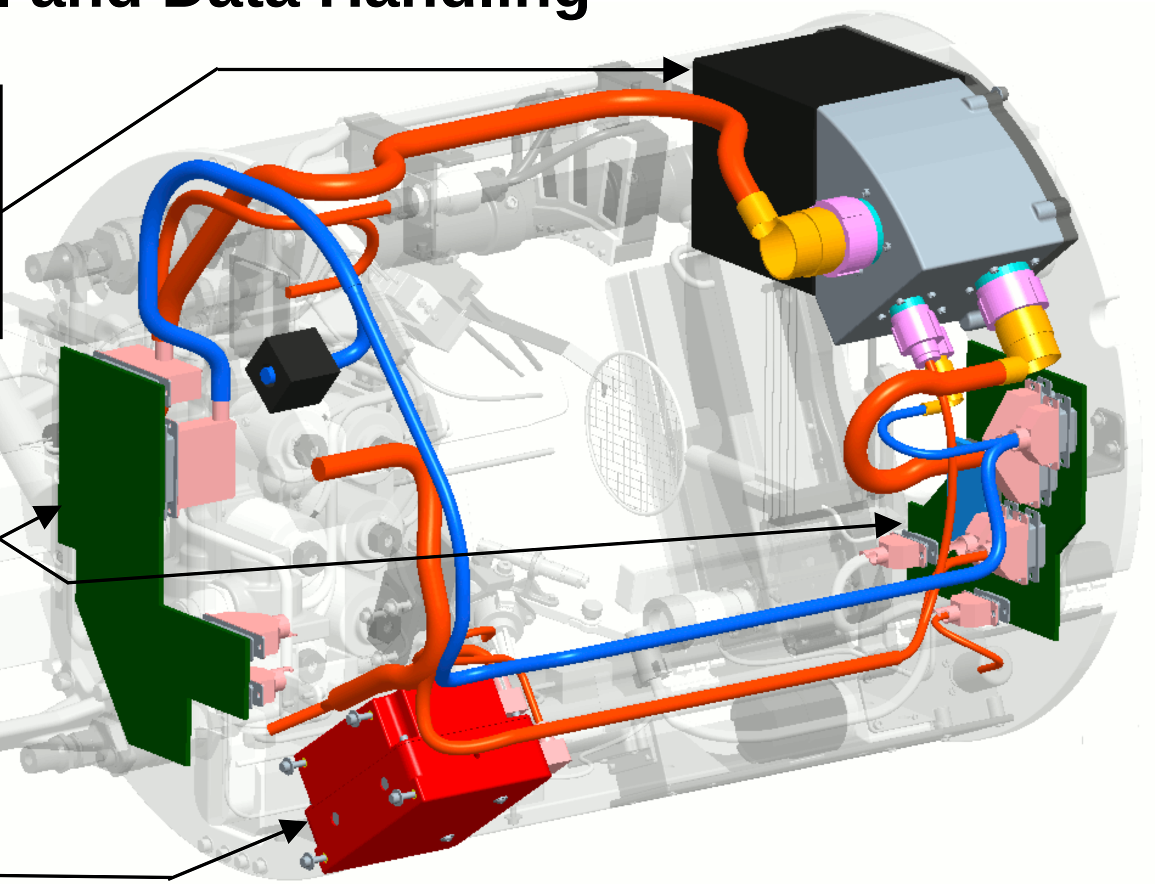


ACME Chamber Insert Assembly
Control and Data Handling

UEI PowerDNA Cube Data Acquisition Unit handles all inputs and outputs inside the CIA except for motor control

Relay Boards handle component switching, power distribution and data routing to the Data Acquisition Unit

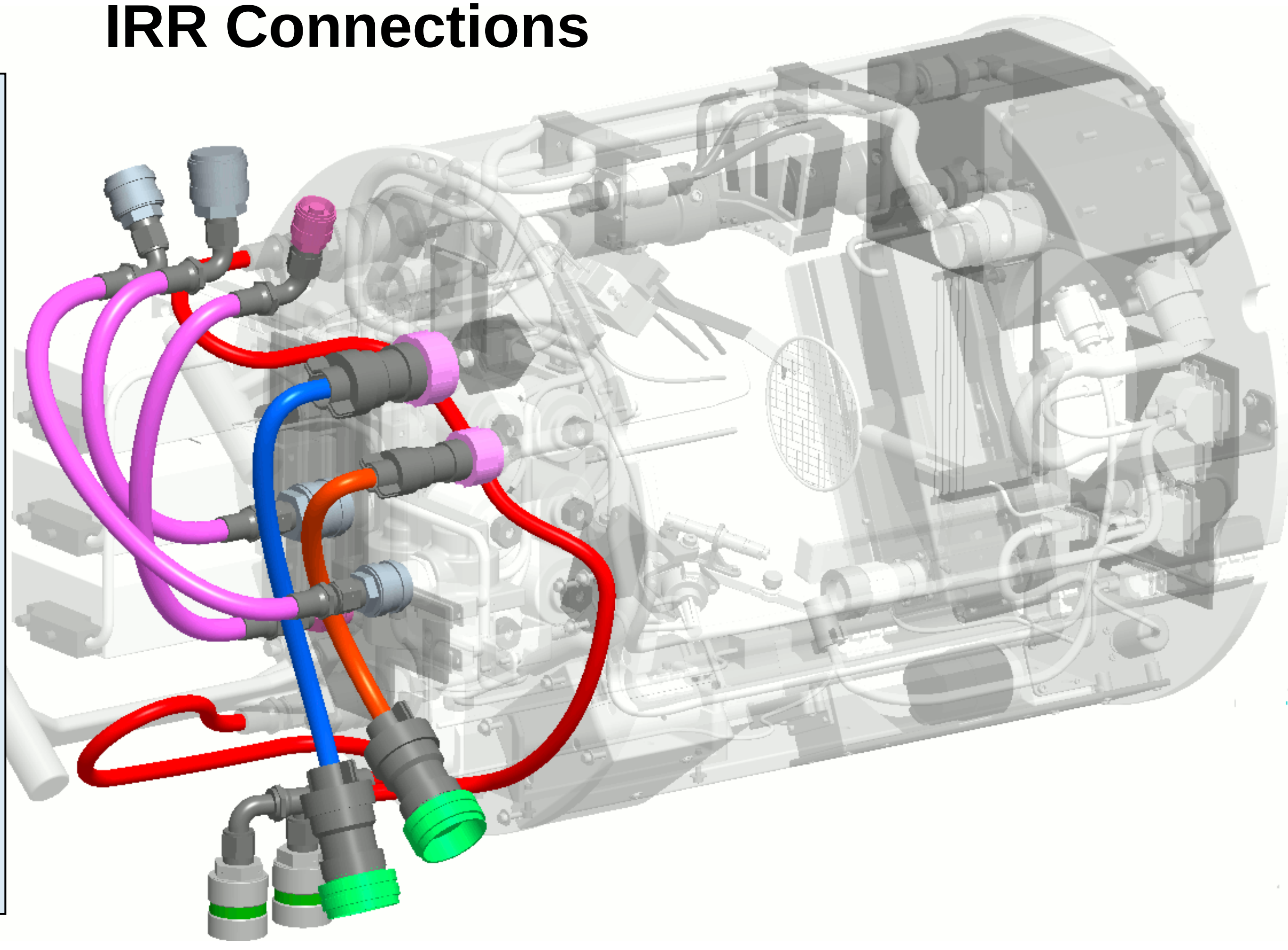
Driver boards controlled by the Motion Control Board inside the AVP control Igniter and TFP Motors



ACME Chamber Insert Assembly
IRR Connections

Consists of the following removable hoses and cables:

- Three gas hoses
- Two water cooling hoses
- Two Electrical Connections to provide adequate power distribution, communication and control for the insert



Advanced Combustion via Microgravity Experiments (ACME)

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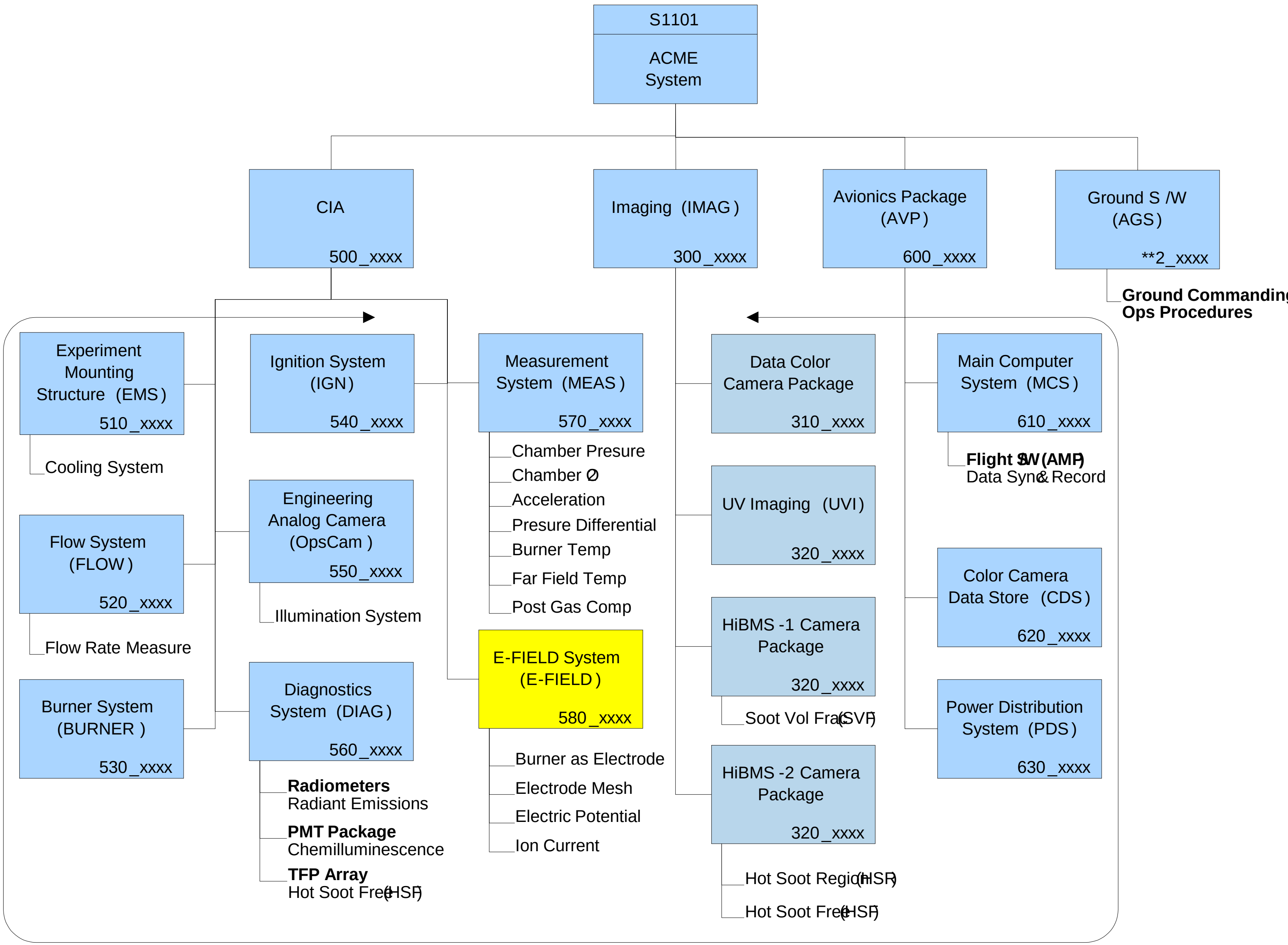


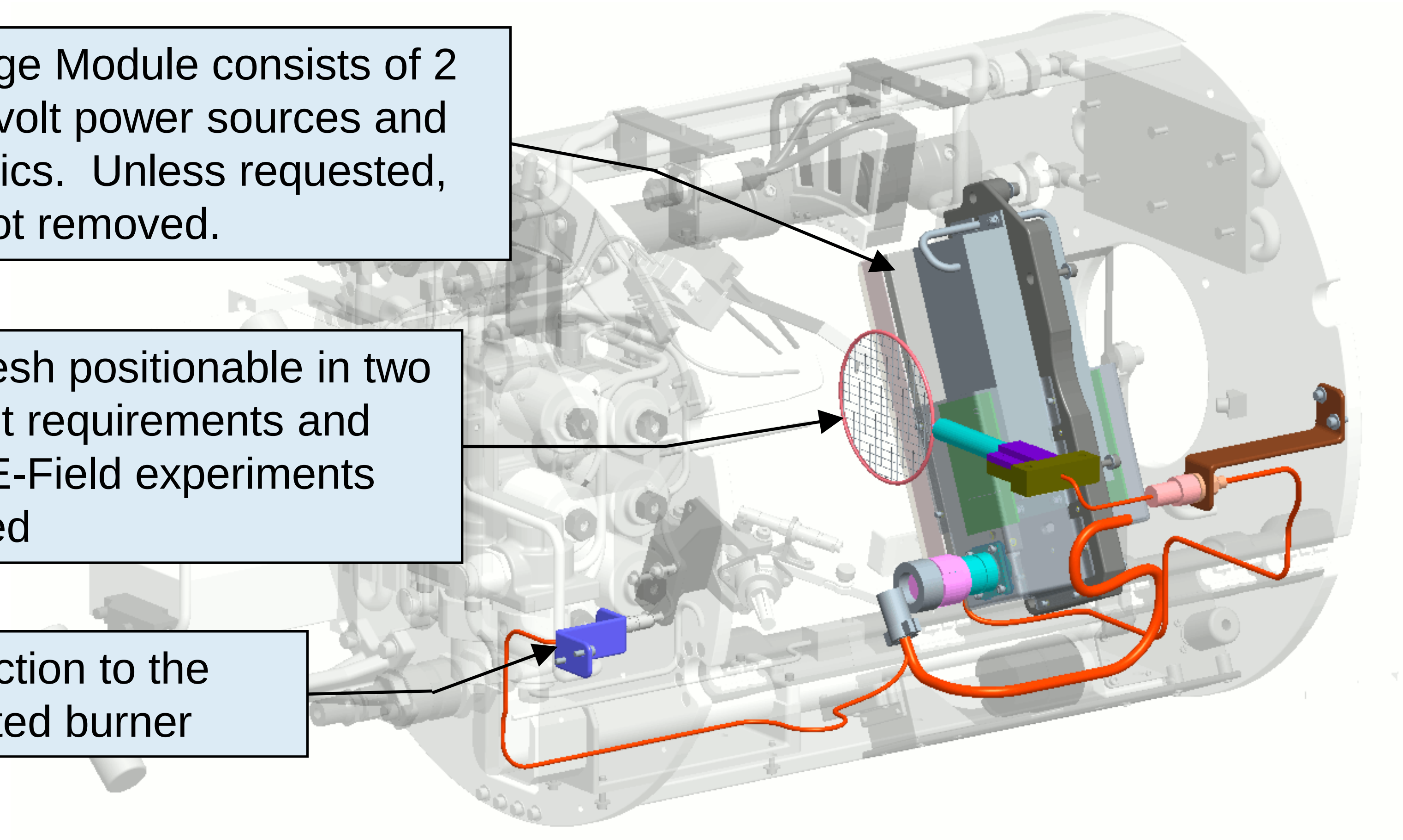
ACME Subsystems

ACME Chamber Insert Assembly
E-Field System

ORU High Voltage Module consists of 2 20A series Ultravolt power sources and passive electronics. Unless requested, this module is not removed.

ORU Copper Mesh positionable in two locations to meet requirements and removed when E-Field experiments are not performed

Electrical connection to the electrically isolated burner



Software Design

Mike Medved
ACME Software Engineering Lead

ACME Software

- ACME has two CSCIs:
  - ACME Main Processor (AMP) CSCI
    - Runs in AVP
  - ACME Ground Software (AGS) CSCI
    - Runs on TSC Workstation

- Both are 7150.2 Class C software – “Mission Support Software”
  - “Flight or ground software that is necessary for the science return from a single (non-primary) instrument.”

7150.2A Requirements

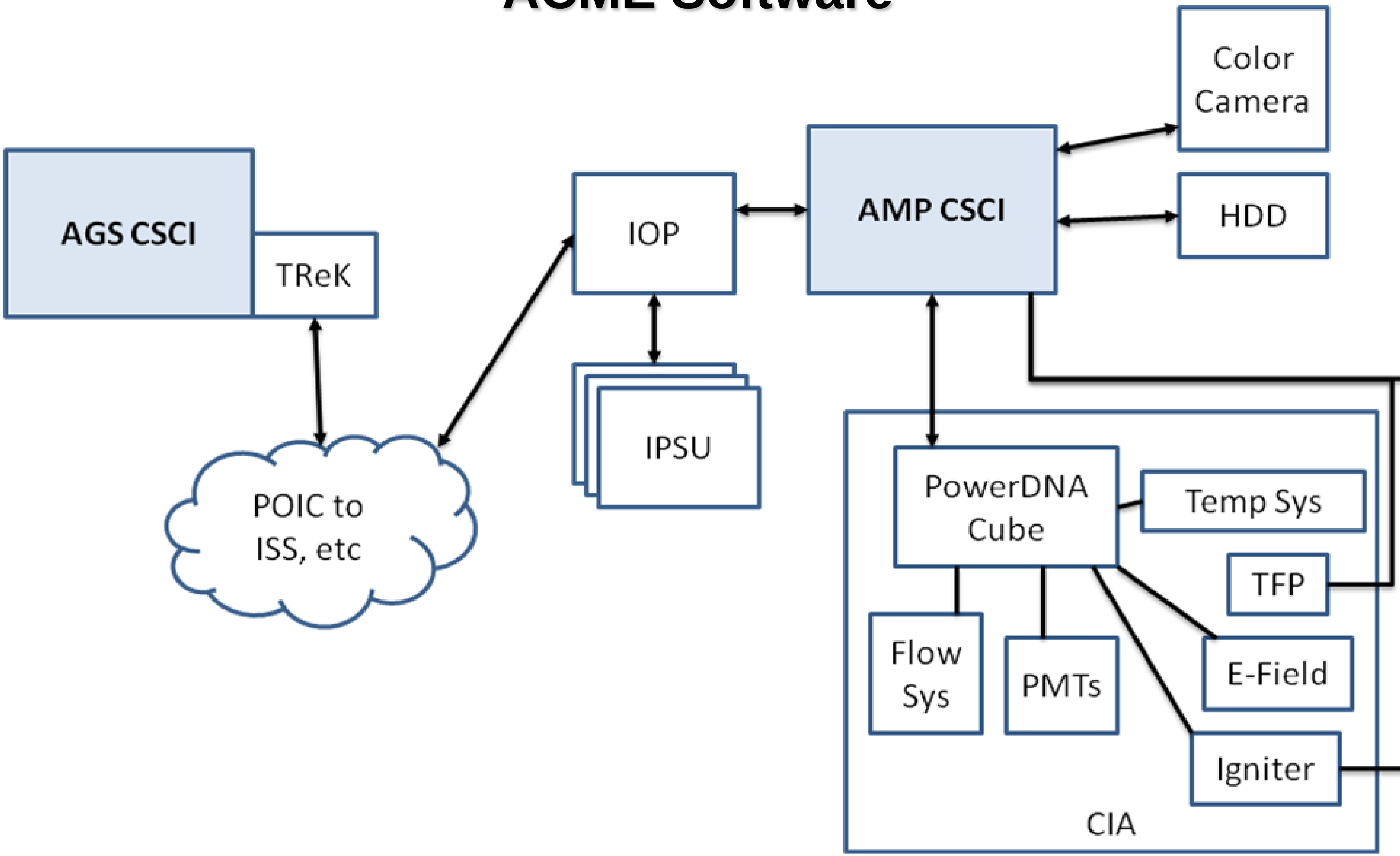
- Main Software Documents
  - Software Management Plan (SMP) *(ACME-PLN-004)*
  - Software Requirement Specification (SRS) *(ACME-REQ-004)*
  - Software Design Document (SDD) *(ACME-DOC-005)*
  - Software Assurance Plan (SQAP) *(ACME-PLN-005)*
  - Software Maintenance Plan
  - Interface Design Description (IDD)
  - Software Test Plan (STP) *(ACME-PLN-009)*
  - Software Test Procedures

- Some documents are covered at the contract level
  - SpaceDOC CM Plan *(P30016)*
  - SpaceDOC Risk Management Plan *(P30015)*

Software Development

- Development occurs according to a basic waterfall
  - In step with the hardware development & NASA review cycle
  - Software development tracked at the project level by ZIN PM
- Requirements documented in “shall” statements in SRS
- Design captured in UML Model
  - SDD dumped from Model
  - Main artifacts include
- Prototyping concurrent with Design on breadboard system
- Requirements verified and validated

ACME Software



ACME Flight Software (AMP)

- Core Capabilities:
  - Communication with CIR IOP
    - Send/Recv commands and telemetry
    - Send imagery and data files
    - Activate IPSUs
  - Color Camera
    - Send commands and change parameters
    - Capture and store images
  - Ops Camera
    - Send configuration commands (gain)

ACME Flight Software (AMP)

- Communicate with PowerDNA Cube
  - Handle Analog Input and Output to Devices

- Communicate with PMD motion control boards
  - Configure different axis for movement
  - Command motion

- Handle experiment execution

ACME Flight Software (AMP)

- POSIX compliant code
  - 10 kSLOC estimate

- Linux Operating System
  - With RT patch
  - TinyCore distribution (~10 MB)
  - Includes Ethernet, Serial, and other drivers

- Vendor Libraries
  - PowerDNA
    - Analog/Digital I/O control of the cube over Ethernet
    - ~35 kSLOC
  - AlliedVision Technologies
    - Interface to the digital camera
    - No source, estimated ~10 kSLOC
  - PMD Motion
    - Motion Control (TFP, Igniter, Lens Zoom & Iris)
    - ~2.5 kSLOC

ACME Experiment Execution Concept

- MDCA had an “automated sequence”
  - Preprogrammed set of steps that always happens in the same order
  - Parameters to those steps affect how the experiment runs

- ACME concept is to allow users to build their own sequences
  - Steps of commands like:
    - move igniter
    - configure flow system
    - begin capturing data
    - start IPSU acquisition

Advanced Combustion via Microgravity Experiments (ACME)

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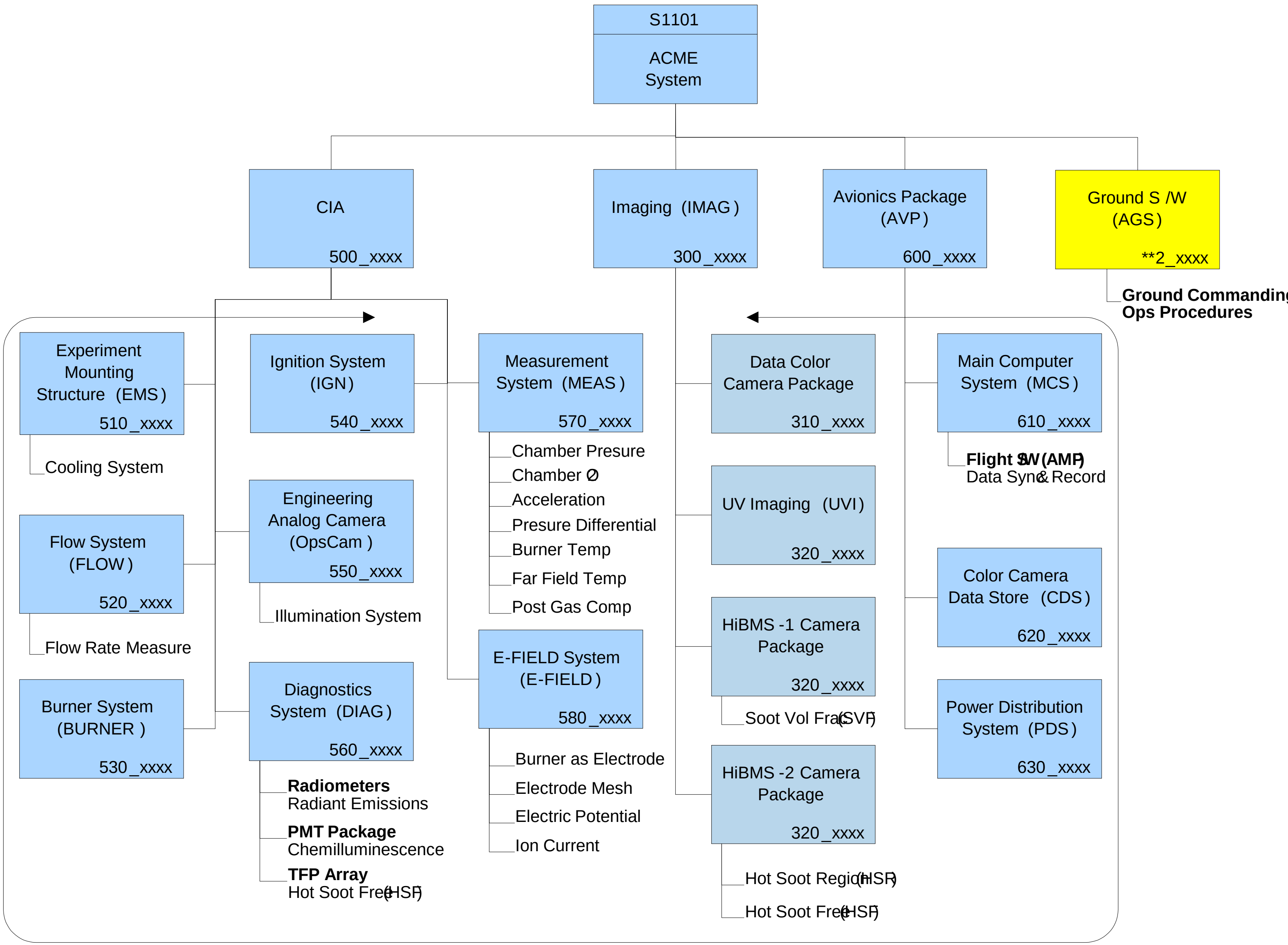


ACME Subsystems

ACME Ground Software (AGS)

- Runs on a TSC workstation (Windows)
- Uses the TReK network to communicate
- Development is delayed in comparison to AMP CSCI
- Capabilities:
  - Send single commands
  - Build and send sequences of commands
  - Request and display telemetry
  - Display health and status
  - 15-20 kSLOC estimate

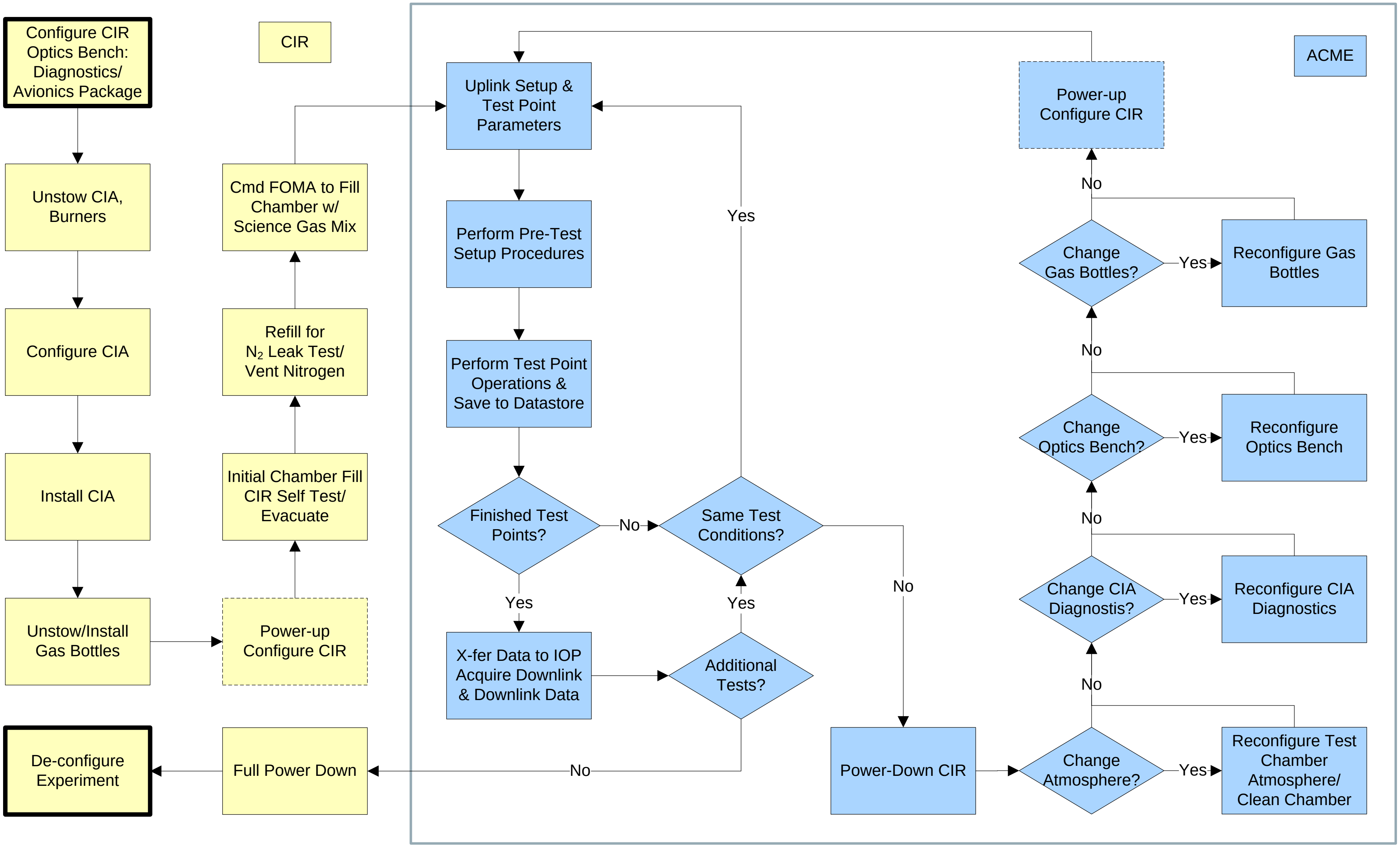
ACME Concept of Operations

Kurt Adney
ACME Systems Engineering Lead

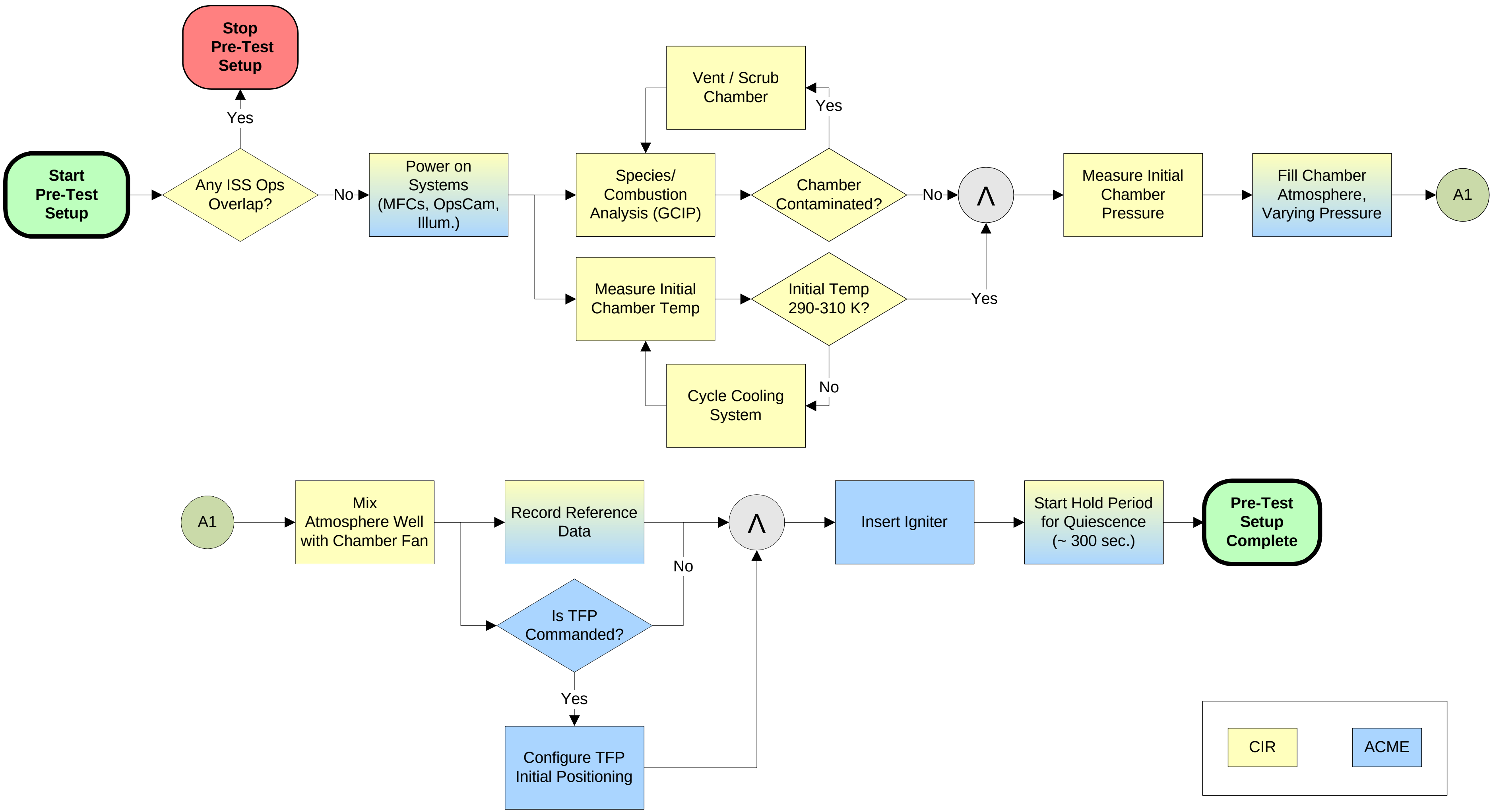
Advanced Combustion via Microgravity Experiments (ACME)

Glenn Research Center

ACME Concept of Operations Flow



ACME Pre-Test Setup Conops Flow



ACME Nominal Test Sequence

The following sequence is made up of the steps that are taken in flowing and igniting gases and is referred to as a sequence:

1. Hardware Set Up
2. Chamber Fill
3. Initiate - *e.g., data acquisition for reference*
4. Ignition – *skipped when there is no flame (e.g., to test electric field current leakage)*
   1. With Pre-Flow
   2. Without Pre-Flow
5. Flame – *many variations which end with time or extinction detection, and can repeat or alternate*
   1. Flame with Fixed TFP Array and No Electric Field
      - Steady Flow
      - Stepped Flow
      - Ramped Flow
      - Rectangular Wave Flow
      - Sawtooth Flow

ACME Nominal Test Sequence (con't)

2. Steady-Flow Flame with Translating TFP Array and No Electric Field
   - Stepped Array Motion
   - Ramped Array Motion
   - Rectangular Wave Array Motion
   - Sawtooth Array Motion
3. Flame with Steady Electric Field (and retracted TFP array)
   - Steady Flow
   - Stepped Flow
   - Ramped Flow
   - Rectangular Wave Flow
   - Sawtooth Flow
4. Steady-Flow Flame with Unsteady Electric Field (and retracted TFP array)
   - Stepped Voltage
   - Ramped Voltage
   - Rectangular Wave Voltage
   - Sawtooth Voltage

ACME Nominal Test Sequence (con’t)

6. Extinction - 2 planned variations
   - Flow Stop
   - Flow Step - *which can lead back to step 4 if flame is again detected*
7. Electric Field with No Flame – 5 planned variations *which end with time*
   - Steady Voltage
   - Stepped Voltage
   - Ramped Voltage
   - Rectangular Wave
   - Sawtooth
8. Terminate - *e.g., data acquisition after acquisition of reference data*
9. Post-Test Ops

ACME Preliminary Gas Bottle Usage Estimates

Flame Design

- 1-“small” (non-standard)* H_2 (shared with S-Flame)
- 2-“small” C_2H_4
- 1-“small” 44.4/55.6 H_2/CH_4 (shared with S-Flame)
- 1-“small” 55.6/44.4 H_2/CH_4 (shared with S-Flame)
- 1-“small” 66.7/33.3 H_2/CH_4 (shared with S-Flame)
- 4-1 L 85/15 O_2/N_2
- 4-1 L 85/15 O_2/He
- 1-2.25 L He

** “small” bottle is a concept currently being worked with CIR to use a smaller than standard gas bottle. Proposed volume would be <= .3 L. In addition to not needed the extra bottle volume, the smaller bottle can also be used as a hazard control if necessary following analyses. This concept has been worked preliminarily with CIR and the feasibility exists. Further design, planning and procedures are necessary before baselining this approach. Backup plan would be to use standard 1 L bottles*

ACME Preliminary Gas Bottle Usage Estimates

S-Flame

•1-“small” CH4
•1-“small” C2H4
•1-1 L 85/15 O2/N2
•1-1 L 85/15 O2/He
•1-3.8 L He
(note: in addition to 4 “small” bottles shared with Flame Design experiment)

CLD Flame

•2-3.8 L Air
•1-”small” CH4
•1-”small” C2H4

E-Field

•1-”small” CH4
•1-”small” C2H4
•1-1 L 85/15 O2/N2
•1 -1L 85/15 O2/CO2
•1-2.25 L CO2

ACME Ground Operations Concept

- ACME will support on-orbit operations with real-time ground operations using the GRC Telescience Support Center (TSC) Facilities, Ground Support Personnel, and Ground Support Interfaces
- Experiment data will be downlinked to ACME for data processing and storage.

TSC Capabilities Required by ACME

- Housing for the GSP console operators and hardware interfaces
- Payload Commanding
- Telemetry acquisition, distribution, processing, and recording
- ISS voice communications and video display and recording
- Access to Mission Planning Services
- Ground Support Personnel Training
  - Includes personnel from FCF, TSC, ACME, and Principal Investigator (PI)

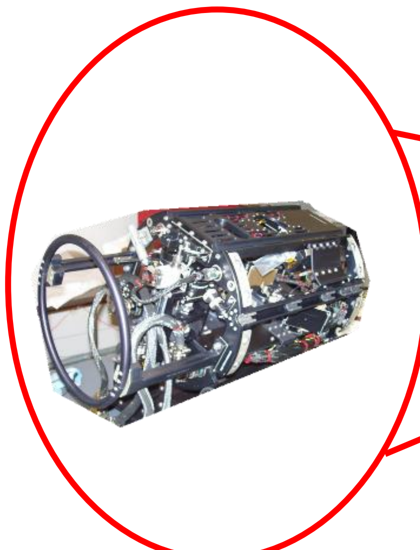
Carrier Integration

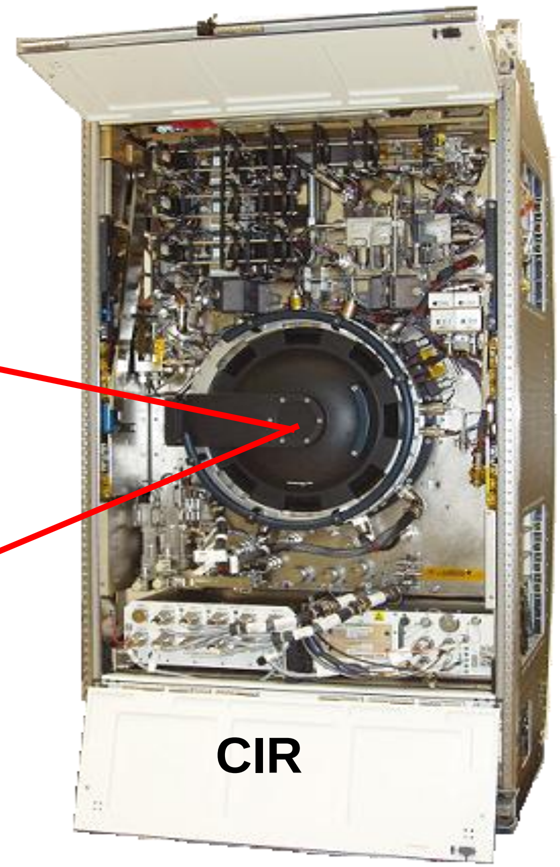
Chris Rogers
ACME Integration Lead

ACME to CIR Integration & Utilization

Advanced Combustion via Microgravity Experiments(ACME)

ACME-specific hardware consisting of an insert installed within CIR’s combustion chamber will include and contain burners, color camera(s), and miscellaneous items like gas bottles, filter cartridges, and igniters.





FCF Utilization Process

- The FCF Utilization Process is defined in FCF-PLN-0875
  - Primary functions of the Integration process are:
    - Payload Planning
    - Mission Integration
    - Engineering Integration
    - Operations Planning
  - FCF/CIR provides the following resources to ACME
    - An integration liaison to assist with the Utilization Process
      - Integrating ACME into CIR
      - Integrating CIR/ACME to ISS
    - Services in support of ACME
      - CIR Provided Hardware (IPSUs, HiBMs, UV Imaging, IOP hard drives, etc)
      - Gas filling services
      - Launch Site Processing Support
      - TADs updates
        - » Further resources provided by CIR and agreements between CIR and ACME are documented in the CIR/ACME Integration Agreement

FCF Utilization Process

- Payload Planning
  - Payload Kick-Off Meeting
    - Documents and Templates
  - Develop ACME to CIR Integration Agreement (IA)
  - Develop ACME to CIR Interface Control Document (ICD)
  - Collect ACME Integration Agreement (IA) Addenda data inputs from ACME and combine inputs for FCF submittal per increment
  - Preliminary Payload Data Collection and Analysis
    - Utilization Tools
    - Payload Data Inputs
  - Payload-Unique Integration Documentation
    - IA Main Volume (MV)
      - Utilization Schedule
    - External Preliminary Interface Revision Notices (PIRNs)/ Change Requests (CRs)/Exceptions

FCF Utilization Process

- Mission Integration
  - Integration Documentation
    - FCF IA with ISS
      - Payload Data Library Data Set
    - Interface Control Document (ICD)
    - Payload Verification Plan (PVPs)
    - Payload Tactical Plan (PTP)
    - Payload Increment 2-Pagers
    - Experiment Science Summary
    - Internal PIRNs/CRs/Exceptions
    - Collect MDCA Integration Agreement (IA) Data Set inputs from MDCA and combine inputs for FCF submittal per increment
  - Payload Launch Processing
    - Manifesting
    - Launch Vehicle Identification and Requirement Definition
    - Hardware Processing and Turnover

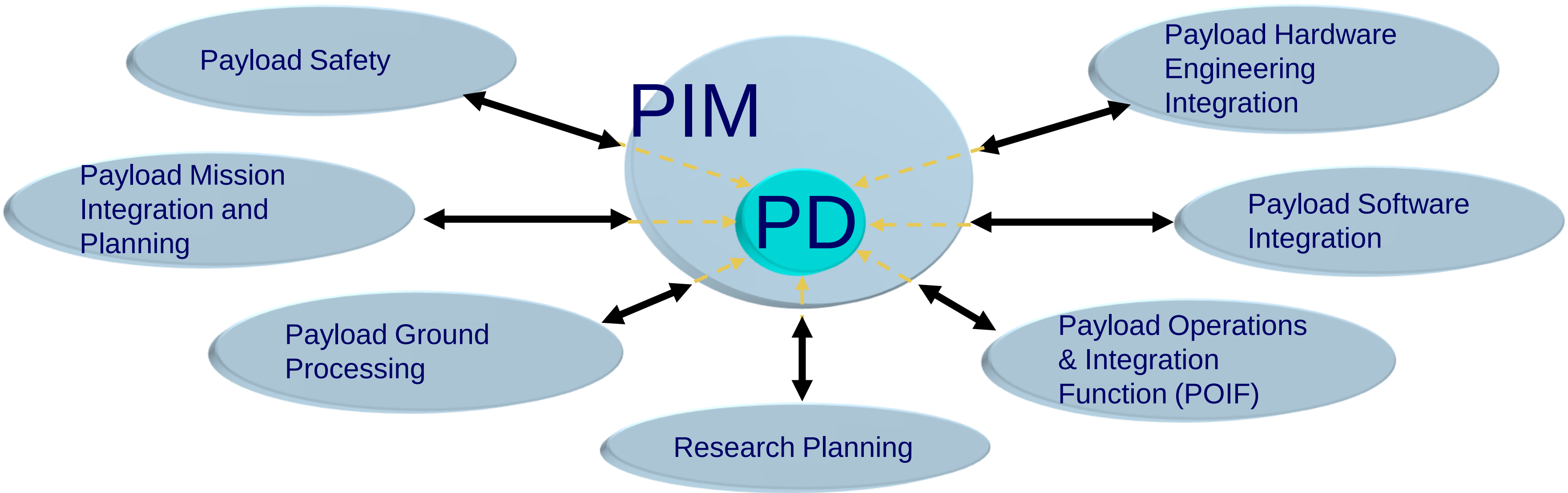
FCF Utilization Process

- Engineering
  - Engineering Integration
    - FCF to Payload Compatibility Assessment
    - Ground Processing
    - Payload Testing, Reviews and Certification
    - Ground Operations
  - Sustaining Engineering
    - Logistics and Maintenance
  - Develop and maintain MDCA to CIR integration schedule

ACME/CIR to ISS Integration

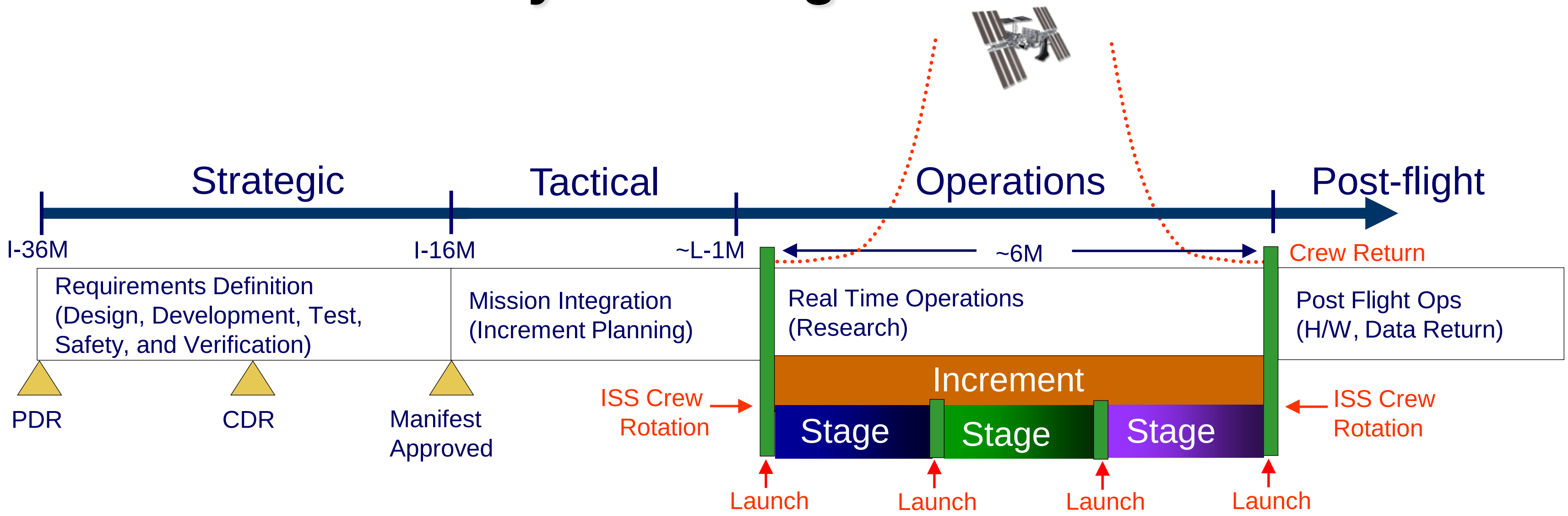
Payload Integration Manager (PIM)

- NASA Payload Integration Manager (PIM)
  - Functions as the Payload Developer's primary interface to the ISS Program
  - Serves as payload advocate – but also protects ISS Program Requirements



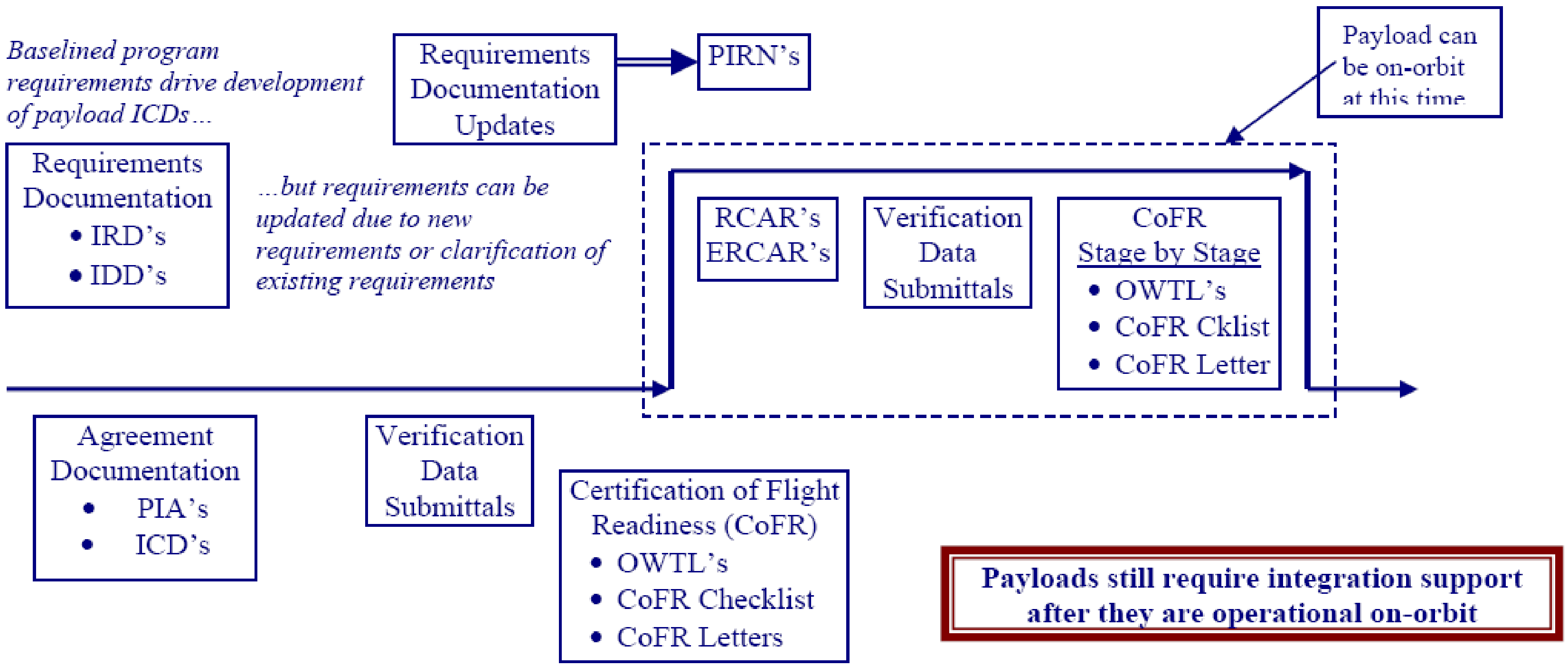
  - Ensures payload requirements are accurately defined and documented
  - Facilitates payload integration product development, delivery schedules, and communications with the ISS Program

ISS Payload Integration Process



- NASA PIMs provide integration leadership during all phases of the payload's life cycle
  - Strategic – ISS integration requirements, products, and schedule development to ensure that an ISS compatible payload is built; support manifest process (payload data collection and feasibility assessments)
  - Tactical – represent PD interests to Increment and Flight-specific teams to ensure that integration and operations requirements are addressed; provide oversight for payload CoFR and verification submittals
  - Operations – assist with operations issue resolution between the PD and the Increment Payload Manager; maintains payload insight; and coordinates payload resupply or return requirements; assure payload CoFR and verification submittals during payload lifetime on-orbit
  - Post-flight – coordinate vehicle deintegration requirements; return of payload material from the landing site to the PD; and Lessons Learned submittals

Integration to Flight Operations Flow



Advanced Combustion via Microgravity Experiments (ACME)

- Operations Integration Products
  - Training
    - Crew Training products and services to properly familiarize Astronauts with payload hardware, use and operation
    - Train ground support personnel for on-orbit operations
  - ISS Resource planning
    - Submit request for ISS Resource requirements necessary for payload operations
- Ground & On-orbit Operations
  - Launch/Landing Site Processing
    - Provides real time support in preparation for launch
    - Retrieval of time sensitive samples from landing site
  - Bench Reviews
    - Act on behalf of payload during final crew review and inspections prior to final packing
    - Verify required packing requirements met
  - Continued on-orbit support of operations
    - Perform real time operations
    - Resolve on orbit issues or problems as they arise

ISS Payload Integration

- ISS Payload Integration facilitates support from concept through on-orbit operations. Also known as the End-to-end Integration Process

  - Payload Planning
    - Perform initial planning and evaluate mission criteria
    - Define roles and responsibilities

  - Mission Integration
    - Planning and ISS Data Set Submittals
    - ISS Program Level schedules
      - Based on projected launch or hardware completion date
      - Identifies major milestones leading up to launch and operations
    - ISS Documentation
      - Provide access to ISS Documentation
      - Write and maintain payload unique documentation for the ISS Program

Advanced Combustion via Microgravity Experiments (ACME)

- Payload Engineering Integration
  - Assist in requirement identification, verification and verification submittal
    - Includes:
      - » identification of unique requirements for multiple launch vehicles
      - » on-orbit requirements from ISS
      - » Requirements unique to the payload
  - Assistance with Safety Reviews and Safety Data Packages
  - Issue Resolution
    - Identification of problems or issues at the ISS Program Level
    - Work directly with ISS Program Offices to mitigate and resolve issues.
  - Manifesting
    - Submit required manifest requests and associated data
    - Identify launch restrictions or packaging constraints unique to payload hardware

Important ISS Documents

- SSP57000- Pressurized Payloads Interface Requirements
- SSP57057- ISS Payload Integration Template
- SSP57217- FCF Combustion Integrated Rack Hardware Interface Control Document
- SSP57008- Unique Pressurized Payload Non-Rack Interface Control Document Template
- SSP57008 Appendix P- Common Transport Requirements

Additional Resources *(available to US-developed payloads)*

Human Factors Integration Team (HFIT)

- Provides guidance/help on Human Factor Requirements
  - except for Acoustics, Touch Temp, and Safety
- Payload does not need to use HFIT, but must still meet HFIT requirements
- Engaging HFIT early in design process can avoid costly redesign later

ISS Payload Label Approval Team (IPLAT)

- Mandatory process and mandatory reviewer of OpsNom
- Ensures payload labeling meets the requirements in SSP 57000, Appendix C
- IPLAT label approval allows ISS Program to provide payload decals and labels to Payload Developer at no cost

Acoustics Working Group (AWG)

- Ensures acoustic levels are low enough to prevent temporary and permanent hearing loss, enable effective communications, and for general crew comfort
- Provides overview and support of flight hardware design against acoustics requirements, provides Acoustic Lab testing capabilities and supports payload testing, ensures payload compliance with acoustic specifications

Electrical, Electronic, and Electromechanical (EEE) Team

- Helps Payload select parts qualified for space environment and mission requirements
- Selected parts understood by SR&QA to simplify safety panel approval
- Provides guidance on vendor selection, screening guidelines, test definition, and testing

Telescience Resource Kit (TReK)

- Free, PC-based telemetry and command system developed by the POIF at MSFC
- Enables payload scientists and engineers to monitor and control ISS experiments from their home offices and laboratories
- Point of Contact: Michelle Schneider, 256-544-1535, michelle.schneider@nasa.gov
- http://trek.msfc.nasa.gov/

Safety, Risk Management & Quality Assurance

Wayne Borrelli
ACME SRM&QA Engineer

ACME Product Assurance Plan

•Utilizes SpaceDOC Safety and Mission Assurance Plan (SMAP) with ACME Product Assurance Requirements Checklist ACME-PLN-011.

•Product Assurance requirements are defined in the GRC‟s Standard Assurance Requirements (SAR) and AS9100.

•Safety and Mission Assurance Plan includes:
- •Product Verification
- •System Safety
- •EEE Parts Control Requirements
- •Materials & Processes Requirements
- •Reliability/Maintainability Requirements
- •Quality Assurance Requirements
- •Contamination Control Requirements
- •Control of Government Property
- •Software Assurance

ACME Product Assurance

Detailed responsibilities of Product Assurance Organization including the following subgroups:

- Reliability and Maintainability Engineering
- Safety Engineering
- Materials & Processing Engineering
- Software Product Assurance
- Product Assurance Engineering
- Continuous Risk Management

The following activities will be monitored and/or verified by Product Assurance:

- Identification and Traceability Requirements (Parts Kitting Lists)
- Procurement Requirements
- Activities for Receiving Inspection
- Control of Fabrication and Assembly Activities (Process Plans, Procedures)
- Plan for Contamination Control
- Details for Electrostatic Discharge Control (ESD)

ACME Product Assurance

•A Nonconformance Report (NCR) system has been made available on-line. There are currently no NCR's that have been generated for ACME.

•A Metrology system is established to meet requirements as stated in ANSI/NCSL Z540-1-11994.

•A GRC Risk Management Database (RMIT) is utilized by ACME for entering and tracking project risks.

•Drawings, documents, and ECO's are tracked and archived through a Configuration Management (CM) system.

ACME Software Product Assurance

ACME Software Product Assurance Plan, ACME-PLN-005

The purpose of this plan is to define the ACME SPA (Software Product Assurance) organization, tasks and responsibilities, provide reference documents and guidelines to perform the SPA activities, provide standards, practices and conventions used in carrying out SPA activities, and provide the tools, techniques and methodologies to support SPA activities and reporting.

Ongoing / Planned S/W PA Support Activities

•Review of software documentation.

•Peer reviews as needed for ACME S/W life cycle activities.

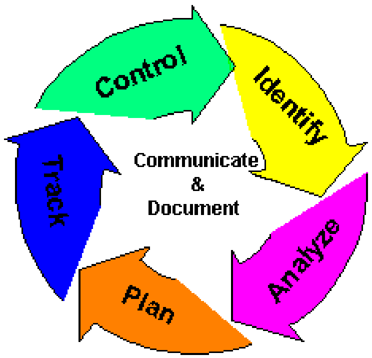
•S/W audits.

•Oversight on ACME S/W verifications.

•Nonconformance Reporting & Corrective Action Process – S/W issues recorded in SpaceDOC NCR system.

•Support of software development lifecycle milestone activities (PDR, CDR, SAR, etc.).

ACME Risk Management



- SpaceDOC Risk Management Plan P30015

- GRC RMIT Risk Management Database
  - Utilized to assist in the continuous risk management process.
  - Online input/processing/reporting of risk information.

- Risk Mgmt Working Group meets monthly to perform risk management activities.
  - ACME Systems Lead supports this meeting.

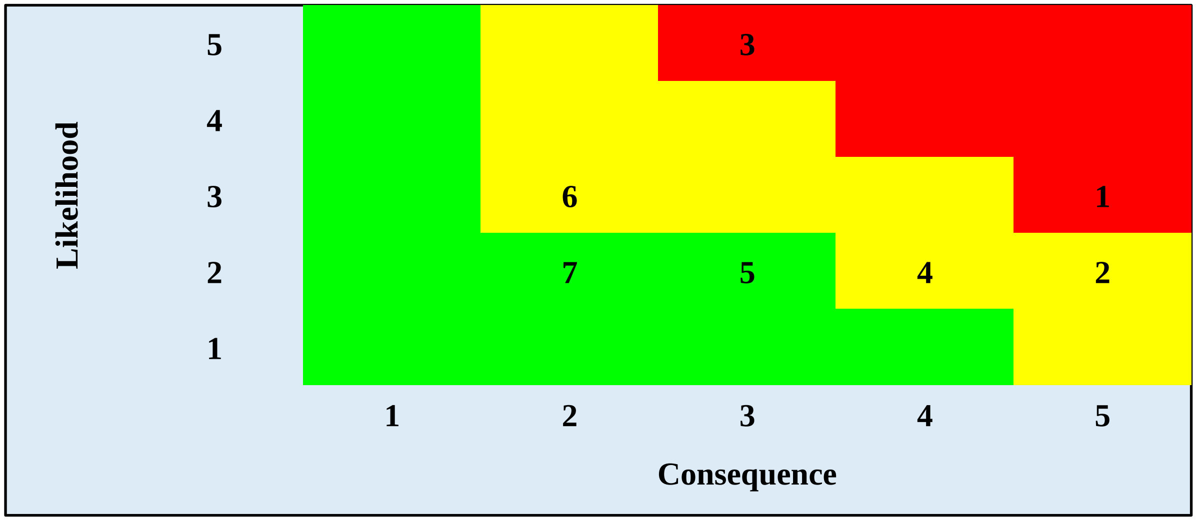
- 15 ACME Risks have been identified to this point in time (8 closed):

  5 Technical Risks

  1 Management Risk

  1 Safety Risk

ACME Top Risks



Rank	ID	Approach	Title
1	ACME-009	Mitigate	ACME radiation susceptibility
2	ACME-010	Research	Cube and fuel mixture compatibility
3	ACME-014	Mitigate	IPSU to IOP image transfer rates take too long
4	ACME-015	-	TSC-ACME ICD documentation not updated
5	ACME-008	Mitigate	E-field emission exceedences
6	ACME-003	Research	Inability to perform inverse flame experiments.
7	ACME-013	Watch	Tin whiskers

ACME Flight Safety Status

•ACME Flight Phase 0/1 Flight Safety Data Package in process.

•Phase 0/1 preliminary standard and unique Hazard Reports have been generated.

•Phase 0/1 FSDP Submittal to PSRP planned for January 2012.

•ACME PSE is currently David Cho

ACME Phase 0/1 Flight Safety Review to be scheduled for February 2012.

ACME Phase 0/1 Flight Safety Data Package
Preliminary Hazard Reports

STD-ACME-1: JSC Form 1230 Payload Standardized Hazard Control Report

ACME-2: Rupture of CIR Combustion Chamber or CIR Exhaust Vent Package

ACME-3: Leakage of Water Cooling System

ACME-4: Rupture of Water Cooling System

ACME-5: Crew Exposure to Broken Materials

ACME-6: Enhanced Flammability Due to High Oxygen Concentration (inside the CIR Combustion Chamber)

ACME Phase 0/1 Ground Safety Data Package

Ground safety documentation will be assembled after it is determined which launch vehicle ACME will likely be utilizing for transport to ISS.

ACME Requirements Compliance

Kurt Adney
ACME Systems Engineering Lead

Requirements Compliance

- Initial Science Requirements compliance has been completed to show that there are no non-compliances with any science requirement

- All ACME requirements will be met by
  – Utilizing common sub-systems to achieve overall ACME goals
  – Leveraging where appropriate off of MDCA heritage
  – Using CIR/ISS provided capabilities
  – Developing custom solutions when necessary

ACME Requirements Verification

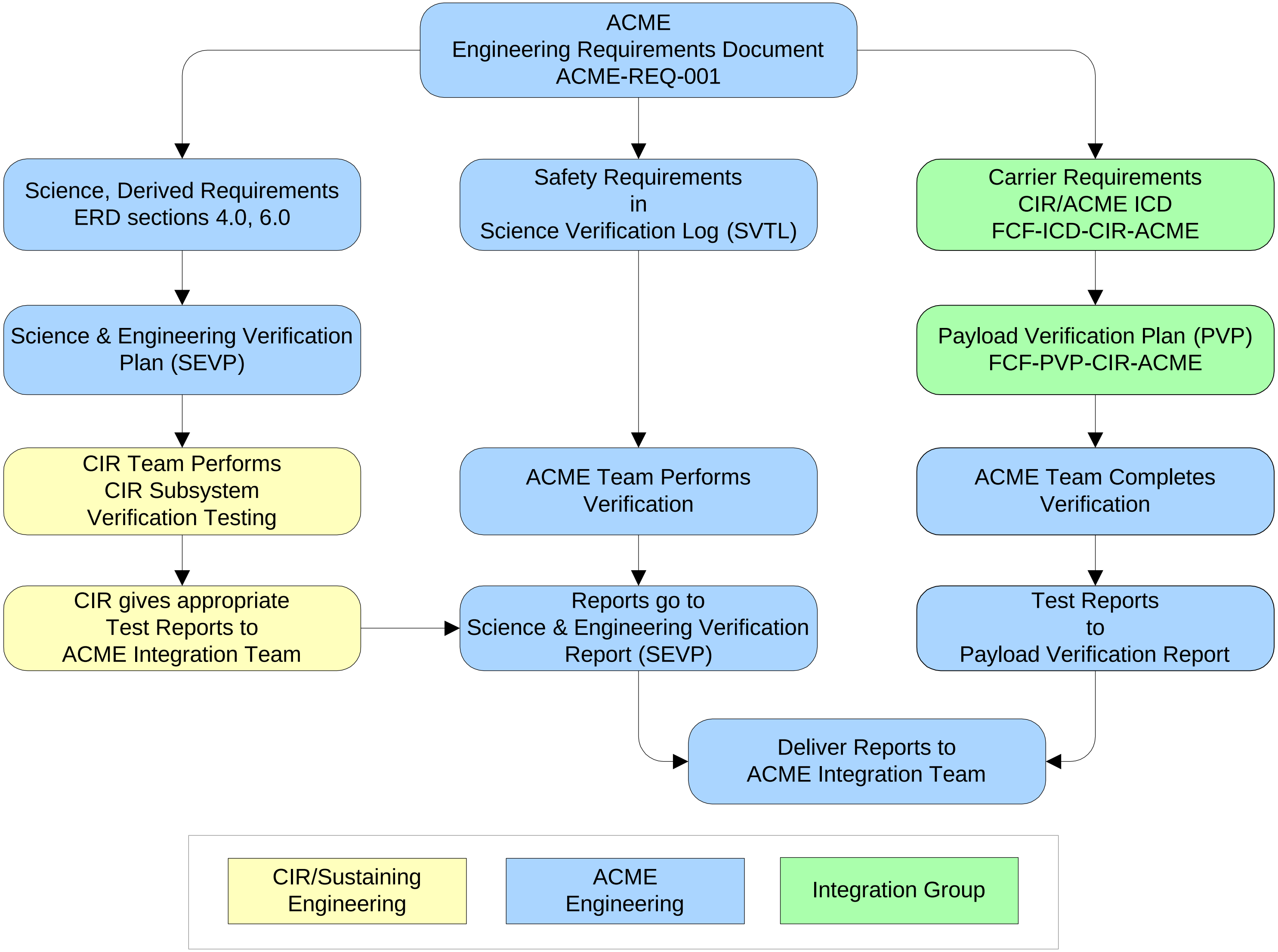
Kurt Adney
ACME Systems Engineering Lead

ACME Requirements Verification

- ACME and CIR will verify system performance
  - Science and Derived Requirements in ERD are verified in the Science and Engineering Verification Report
    - ACME verifies requirements as called out in the ERD as being their responsibility.
    - CIR verifies their component performance per their requirements and reports results to ACME via the Integration Team. ACME then assesses compliance to ACME requirements

- ACME will verify payload requirements
  - Carrier and Safety requirements in ERD are verified in the Payload Verification Report
    - ACME verifies requirements as called out in the ERD
    - ACME delivers Payload Verification Report to CIR

ACME Requirements Verification



ACME Project Readiness

•ACME has conducted thorough analysis of requirements and has produced a complete functional decomposition of sub-systems necessary to address all requirements

•The current ACME design adequately addresses all elements of the functional decomposition and thus all requirements

•Mature Pro-E models exist for all ACME sub-systems, including integration of each into system level assemblies.

•Sub-system and system level testing has been successfully completed for each design and have demonstrated requirement compliance, feasibility and adequate sub-system interaction